# How Children Grow

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Ruth Sawtell Wallis

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AND THE
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# HOW CHILDREN GROW

## An Anthropometric Study of Private School Children from Two to Eight Years of Age

by

RUTH SAWTELL WALLIS, Ph.D.

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To

Franz Boas

great leader in the study of growth
who has taught many smaller minds to grow

Bureau Ednl. Psy. Research
DAVID HARE TRAINING COLLEGE
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# FOREWORD

The appearance of this monograph in a University of Iowa series is made possible through the generous coöperation of Mrs. Lucy Sprague Mitchell, Director of the Bureau of Educational Experiments, New York. Dr. Wallis' study is a report of work done in the Bureau. It represents a community of interest between the Bureau and the Station in the field of physical growth, a field which, in the Station, was most fruitfully explored by the late Bird T. Baldwin.

Growth of children from two to eight years of age is shown most effectively by the method of sequential measurements of the same children. This technique automatically increases the effectiveness of the sample, lessens the number of variables to be controlled, and reduces the amount of statistical inference.

Weight and height are definitely related to economic stratum. Environmental factors tend to mask racial differences. Hence, there is indicated the interesting problem of the role of nutrition as a mediating factor between economic prosperity and physical growth. But Dr. Wallis very properly restricts her study to the facts of growth, without which the further question of *why* children grow lacks meaning.

Her study gives further evidence of a high stability of growth relations among different parts of the body. One senses that the pattern-to-be deviates from its original direction only in response to strong environmental factors; that the whole heredity vs. environment question, in so far as it relates to physical growth, is essentially a matter of a balancing of forces.

Dr. Wallis, by her personal assumption of the arduous task of making all these measurements and fitting them into a carefully prepared plan of attack, shares the same scientific qualities which she has so graciously ascribed to her teachers and associates.

GEORGE D. STODDARD.

Office of the Director
Iowa Child Welfare Research Station
State University of Iowa
July 18, 1931

# PREFACE

In planning a five-year study of the growth of behavior among preschool children at the Bureau of Educational Experiments in New York City it was felt that the physical development of the same children should be considered. A series of anthropometric measurements and roentgenograms was therefore made during the two school years between 1924 and 1926. In September, 1926, an anthropologist, the writer, was added to the research staff to continue and extend the collection of data and to analyze the records. The results, then of five years' measurement and preliminary study and a year of intensive statistical treatment are contained in this monograph.

The groups of children which the Bureau of Educational Experiments had selected for study formed, naturally, the nucleus of the anthropological investigation. These were two, the children in the Bureau's Nursery School with an age range from eighteen months to three years and the children from three to seven years of age in the City and Country School. To extend knowledge and increase reliability, records were continued on the seven- and eight-year-old children previously measured, and data were secured from three other sources so completely comparable in background that the records could be merged with the main groups without separate classification. The Horace Mann School and the nursery school of the Institute of Child Development of Teachers College, Columbia University furnished material for eighty-eight children and thirty-six more were selected from the waiting list of the City and Country School and younger brothers and sisters of those attending the school. Large series of roentgenograms accompanied by simple measurements were studied for purposes of comparison at the Iowa Child Welfare Research Station, the Merrill-Palmer School in Detroit, and the Anatomical Laboratory, School of Medicine, Western Reserve University.

The main body of the material was secured through the coöperation of Miss Caroline Pratt, principal of the City and Country School and Miss Harriet Johnson, director of the nursery school of the Bureau of Educational Experiments. Measurements and roentgenograms of other New York children were obtained through the kindness of Dr. Roland G. Freeman, Jr., of the Institute of Child Development, Professor Arthur I. Gates of Teachers College, and Mrs. McCastline of the Horace Mann School. To those who generously opened their laboratories for days of measuring roentgenograms and copying records particular thanks are due to Dr. George D. Stoddard and Miss S. Idell Pyle of the Iowa Child Welfare Research Station, to Dr. T. Wingate Todd of Western Reserve University, and to Dr. Charles A. Wilson of the Merrill-Palmer School.

The staff employed in assembling the data deserves gratitude. Dr. Ramsay Spillman has contributed far more to the study than fell within the duties of a roentgenologist. That combination of accuracy and courage necessary in applying calipers to the very young was cheerfully supplied by the assistants in anthropometry, Miss Lois Mills, Mrs. Estelle Fine Ritt, and Dr. Eleanor Phelps Hunt. Mr. William Baake made the diagrams from the roentgenograms. The statistical assistance has been given chiefly by Mrs. Clara Fisher Miller and by Miss Carolyn Adler who is now making an independent study of certain phases of the material.

The problem of this anthropological study of growth was originally undertaken and finally carried through with the unfailing interest and counsel of Professor Franz Boas of Columbia University and Dr. Harry L. Shapiro of the American Museum of Natural History.

RUTH SAWTELL WALLIS.

# CHAPTER I

## INTRODUCTION

Big children are big and small children are small. They grow larger as they grow older. Boys and girls are different.

No vast amount of research may seem necessary to produce these evident statements, but as a matter of fact, instead of being obvious remarks accompanying two or three glances at three or four infants, they have emerged from the measurement, remeasurement, selection, rejection, tabulation, and calculation of the past six years. In following the growth of a large number of private school children between the ages of two and eight, it was soon evident that a child develops in accord with his stature. Tall children not only have longer legs and trunks than short children of the same age; they tend also to have wider shoulders and hips, more rapid ossification of the extremities, and a greater number of permanent teeth. Age, of course, is the outstanding factor in growth, but within a group of a year's range the size of any part of the body is more likely to rank according to the individual's height than his age in months. Differences between the sexes vary from practically zero for such characters as stature and arm length to a six or twelve month acceleration in the ossification of the cartilage in the extremities of girls, and the invariably greater robusticity of the limb bones and higher averages for head and face measurements in all groups of boys.

According to age, to stature, and to sex, these are three ways in which children grow. The fact that the material of this study is purely anatomic excludes all possibility of answering why they grow. The fact that it is almost entirely osteologic limits the knowledge of how. The records are mainly of two types, direct measurements taken on the living child and measurements made on roentgenograms of the same individuals. The first group in addition to the composite measures of stature and weight include measurements of the vertical segments of the body such as the trunk and the extremities, the transverse breadths of shoulders and pelvis, and diameters of the head and face. From the roentgenograms of the extremities are derived measures of the processes of ossification of cartilage and growth of bone. To add to the picture of the child, dental records exist at the upper and lower end of the age range.

The anthropological point of view has been the outlook on all the material. The first consideration was to observe what happens within the limits of a carefully defined group and to interpret the results in terms of the average value of a trait always in connection with its variability. Similar heredity, similar environment both physical and economic, and one sex are the basic requirements for classification; in the case of children a narrow age range must be added. When the values of the measurements and derived indices of children grouped to fulfill these conditions are considered in yearly sequence, the observed deviations in absolute size and variability, the changes in bodily proportions, and the amount of sex difference offer a full description of growth. Neither the original aim nor the final result is the establishment of absolute norms or standards for the size of physical characters. There is no implication that a private school group is of greater value for study than any other; it was simply a series offered under conditions favorable for research. Nor has the question of the relation of the results to theoretical growth curves influenced the form of the work.

## CHILDREN

The main group about which this study is centered attended private schools in New York City. The majority are from the City and Country School, a smaller group with fewer measurements from the Horace Mann School, and twenty-nine children from the Institute of Child Development of Columbia University. Moderate prosperity rather than wealth characterizes the background. Most of the City and Country School children live in the Chelsea and Greenwich Village sections; many of the parents of the other two school groups are members of the Columbia faculty. Although the schools give scholarships to poor children, only a very few do not receive the optimum diet throughout the year. Careful school health programs have greatly reduced the spread of the contagious diseases which result in retardation of growth. The children belong, then, to the favored class whose economic environment offers them the possibility of attaining the maximum growth inherent in their family lines. We know that better hygienic conditions and the reduction of malnutrition during the last fifty years have raised the mean adult stature in every country in Europe, and in the United States (9, 34, 49). That this raising of the general mean is not entirely due to improved conditions operating among the lower economic groups is illustrated by the increased stature of three generations of Harvard College students. The study of the statures of 2,000 pairs of fathers and sons being conducted by Gordon S. Bowles of the Division of Anthropology of Harvard, shows that the average stature of the sons greatly exceeds that of the fathers. The latter in their turn are almost as much taller than their own fathers (about 300 pairs). Different average values for stature and weight in different social environments, selected for adults by occupation and for children by types of school, have been established in different sections of the United States and several cities of central Europe (46, 52). As will be evident later, the New York children exceed in the expected manner the height and weight of public school children. Their averages are practically identical with those of two comparative groups from the nursery school of the Merrill-Palmer School in Detroit and the preschool laboratories of the Iowa Child Welfare Research Station. All three groups are of fairly uniform economic background. However, they differ somewhat in racial composition, although all are of European origin. Professor Boas (11) has suggested that while in all probability, each racial type has its own growth curve, the differences between the curves of European types are small as compared to the variations that may be brought about by different social environments. The age range in the present study (two to eight years) lying between the first rapid ascent of the growth curve and the second preadolescent rise, would be least affected by small racial differences. We make no further entry into the conflict between heredity and environment waged often as obscurely in the scientific mind as in the human body and rest outside with the apparent evidence that in three groups of young children with almost identical economic background and considerably diverse European origin, the amount of growth is the same.

### *Groups and Records*

The number of New York private school children is 239. About two-thirds are from the City and Country School. This total, 151, includes thirty-six younger brothers and sisters of those attending school and others on the waiting list. Thirty sets of records were made on children under eighteen months in order to throw light on various growth processes and to obtain early information concerning babies registered for the nursery school. Simple genetic histories, anthropometric measurements, roentgenograms, and dental records make up the types of material gathered. The minimum record of a child in the City and Country group consists of a genetic history, stature, weight, dentition, and a roentgenogram of the forearm taken once. The maximum is these measures covering a period of five years, fourteen other body measurements taken for three years, and roentgenograms of the foot made for two years.

For the children from the other two schools incorporated in the New York private school group, fewer records exist. Each child has only one set. The Horace Mann list consists of stature, weight, and a roentgenogram of the hand for fifty-nine individuals. Seven anthropometric measurements and roentgenograms of forearm and foot are present for the twenty-nine nursery school children of the Institute of Child Development, Teachers College, Columbia University.

The age range of the Merrill-Palmer nursery school children is from two to five years. We have records of stature, weight and stem length, and hand roentgenograms for 150 children, seventy-five boys and seventy-five girls. They come from a good middle class environment with few children of wealth and few poor.

The children from the preschool laboratories of the Iowa Child Welfare Research Station come from homes described as follows: "a number from the homes of university professors or graduate students, some from those of the business men of the town, and a few from good working class homes." (4) Those from the elementary school of the State University of Iowa are from similar backgrounds. Roentgenograms of the hands of 387 of these children from one to eight years of age were measured according to the technique used on the New York and Detroit films. Averages and variabilities of stature and weight for the age and sex groups were secured.[1]

### *Genetic Histories*

For all of the 151 children of the City and Country School, there is a record of the birthplace of the parents and of the four grandparents. The same information was known for 133 of the 150 Merrill-Palmer children, and records were secured for practically all of the Iowa group. The analyses of the histories of parents were made under the following topics: per cent born in and outside of the United States, birthplace of native born parents by regions of the United States, per cent of parents born in the British Empire and in Continental Europe. Amounts of racial stock were estimated by calculating the percentage of grandparents born in various European countries. A separate calculation was made of Jewish stock, both foreign and native born. Dr. Hrdlicka's (31) generally accepted term "Old American" cannot be applied to any individuals or groups since it refers to the third native generation of adults and our information covers only two adult generations. From the following tabulation, it is evident that very nearly the same proportion of American born parents make up the three different groups.

---

[1] Mrs. Helen Garside Kelly, Research Associate in Statistics, Iowa Child Welfare Research Station, furnished these data.

| Place of Birth | Group | | | | | |
|---|---|---|---|---|---|---|
| | New York Private Schools | | Merrill-Palmer Nursery School | | Iowa Child Welfare Research Station | |
| | Number | Per cent | Number | Per cent | Number | Per cent |
| In United States | 270 | 90 | 219 | 82 | 526 | 93 |
| Outside United States | 32 | 10 | 47 | 18 | 38 | 6 |
| In United States and Canada | 275 | 91 | 230 | 86 | 537 | 95 |

Iowa has the lowest per cent of foreign born parents and the highest is from Detroit, not New York. Of the foreign born parents as the following tabulation indicates:

| Place of Birth | Group | | | | | |
|---|---|---|---|---|---|---|
| | New York Private Schools | | Merrill-Palmer Nursery School | | Iowa Child Welfare Research Station | |
| | Number | Per cent | Number | Per cent | Number | Per cent |
| British Empire | 14 | 44 | 18 | 38 | 20 | 53 |
| Continental Europe | 18 | 56 | 29 | 62 | 18 | 47 |

the Iowa residents come more frequently from the British Empire than from Continental Europe; the reverse is true of the other two groups. The distribution of native-born parents by regions of the United States is, unfortunately, not entirely comparable to the rest of the data because of numerous cases in which no birthplace other than United States was recorded.

| Place of Birth | Group | | | | | |
|---|---|---|---|---|---|---|
| | New York Private Schools | | Merrill-Palmer Nursery School | | Iowa Child Welfare Research Station | |
| | Number | Per cent | Number | Per cent | Number | Per cent |
| North and Middle Atlantic | 190 | 73 | 24 | 13 | 30 | 12 |
| South | 18 | 7 | 15 | 8 | 3 | 1 |
| Middle West | 45 | 17 | 135 | 77 | 210 | 84 |
| West | 7 | 3 | 4 | 2 | 7 | 3 |

For the City and Country School, this occurred in only ten cases (4 per cent) but 19 per cent of the Merrill-Palmer and 52 per cent of the Iowa histories were of this type. Individuals born west of Nebraska and South of the District of Columbia are rare in any group. The Iowa group is the most indigenous; this is also true where subdivision is carried to birthplace in the state in which the school is situated. Fifty-five per cent of Iowa parents were born in that state, 48 per cent of City and Country parents in New York and New Jersey, and 45 per cent of Merrill-Palmer parents in Michigan. Even though we cannot safely conclude that the Detroit and Iowa parents for whom we have full histories are fair samples of the whole, it is interesting to note that the group of New York parents interested in experimental education is far more indigenous to a small section of the Atlantic coast than would have been predicted from the popular picture of all progressive America rushing to the island of Manhattan.

An estimate of the racial stocks represented in the children has been attempted on the basis of the birthplace of the grandparents as given below:

Children with Four Native Born Grandparents

| City and Country School | | Merrill-Palmer Nursery School | | Iowa Child Welfare Research Station | |
|---|---|---|---|---|---|
| Number | Per cent | Number | Per cent | Number | Per cent |
| 84 | 56 | 46 | 37 | 133 | 60 |

Children with One, Two, Three or Four, Foreign Born Grandparents

| | City and Country School | | Merrill-Palmer Nursery School | | Iowa Child Welfare Research Station | |
|---|---|---|---|---|---|---|
| Foreign Born Grandparent | Number | Per cent | Number | Per cent | Number | Per cent |
| 1 | 18 | 27 | 18 | 23 | 35 | 40 |
| 2 | 29 | 43 | 30 | 39 | 33 | 38 |
| 3 | 5 | 8 | 7 | 9 | 4 | 5 |
| 4 | 15 | 22 | 23 | 29 | 15 | 17 |

Chief Birthplaces of Foreign Born Grandparents

| | City and Country School | | Merrill-Palmer Nursery School | | Iowa Child Welfare Research Station | |
|---|---|---|---|---|---|---|
| Birthplace | Number | Per cent | Number | Per cent | Number | Per cent |
| British Empire | 52 | 34 | 102 | 53 | 31 | 40 |
| Russia | 34 | 23 | 36 | 19 | 8 | 5 |
| Germany | 24 | 16 | 12 | 6 | 29 | 37 |

The outstanding differences among the three groups are the large number of Canadians in the Merrill-Palmer group which accounts for the low figure for native born grandparents, the greater relative amount of German stock in Iowa, and the distribution of Jewish lines in the three localities. Among the 151 New York children, 18 per cent of the stock is Jewish and in the Merrill-Palmer School, 12 per cent; it is negligible in Iowa. These percentages were derived from the number of children who are a quarter, a half, three-quarters or entirely Jewish. Since, along with the retention of certain physical characteristics, Jews vary in type in the direction of the country of their origin, they are included in the preceding tabulations and the incidence of the stock was calculated as a further description of the children. The largest single element in each foreign born group comes from England and Canada with a scattering from other British possessions. In Iowa, the German born nearly equal this, however, and the combined Russian and German from New York exceeds the British. Russia, which is second in the New York and Detroit groups, is outranked in Iowa by Denmark, the birthplace of 8 per cent of the grandparents. The remaining 20 to 25 per cent of the foreign born of each group, who are not British, German or Russian, come from the different countries of western Europe.

The descriptive analysis of the probable racial origins of three groups of children attending the City and Country School in New York City, the nursery school of the Merrill-Palmer School in Detroit, and the preschool laboratories of Iowa Child Welfare Research Station and elementary schools of the State University of

Iowa shows considerable differences in the relative amounts of the main components. The close correspondence of the measurements of these children between the ages of two and eight years substantiates the theory that for children of European origin a common economic environment is a greater factor in the growth curve than are small hereditary differences.

### *Records of Physical Growth*

*Anthropometric Measurements.*—The process of the anthropometric measurement of children creates perhaps the one situation in which an adult is justified in saying, "This hurts me more than you." The deepest, reddest mark of calipers or finger nail on the softest infant arm fades in a minute, but the anthropometrist, months later, is still agonizing over a leg that shrank instead of grew. This shrinkage may be actual though temporary, due to linear reduction from exercise or fatigue; it may be the result of the very slight development of the tibial head and the consequent obscurity of the landmark; it may be the weariness or unconscious inattention of the operator; or it may be what is solemnly called the uncoöperative attitude of the subject. The two sources of error seemingly least possible to control are the child and his bone development. Fortunately, attacks of rigidity, hilarity, pugilism, and tears in amounts large enough to invalidate the measurements are rare after two years of age, and experience in measuring and repeated measurement of the same individual give a good chance of finding even small bony points on plump children. The problem of physiological reduction can be at least partially solved by measuring the children at the same time of day and following the same kind of school activity, and the anthropometrist's accuracy can be increased as the number of young subjects to be dealt with in a short period of time is diminished. Since, however, we are forced by school programs to take our children when we can get them, these tangible factors of error are in reality often more difficult to eliminate than the mood of the child or the immaturity of his skeleton. Under the best conditions, the general belief of anthropologists, strengthened by the experiments of Dr. T. Wingate Todd (53), is that in measurement of the living from subcutaneous bony landmarks, accuracy within less than five mm. does not exist. Thorough statistical tests of the causes of error acknowledged by all honest measurers of young children have been made recently by Dr. Edith Boyd (14). She concludes that the greatest danger lies in the single reading of a given measurement on a single individual. The possibility of a monthly increment being completely masked by the experimental error has also been pointed out by Boyd and further illustrated by Hejinian and Hatt (26).

In this study the fully recognized factors of unreliability have been met in the manner best suited to the working conditions. Although the program of the City and Country School made it impossible to measure every child at the same time of day, children of the same age group were examined with nearly complete uniformity. Children from the three and four-year-old classes came to the laboratory between nine and twelve, those in the five and six-year-old classes between two and three-thirty in the afternoon, and the older children (seven and eight years) between three-thirty and four-thirty. This schedule was maintained regularly during the three years that the writer was in charge. All measurements included in this study, except some records of stature and weight, were made during that time. One person (the writer) with six years' previous experience in physical anthropology, took part in every measurement and was responsible for all landmarks. An assistant checked. The presence of a reliable recorder with no other duty to perform and a fourth person to dress the children contributed a large amount of peace and accuracy to the anthropologist's performance. The children themselves were on the whole excellent subjects; very few were not charmed by the undivided attention of two or three adults.

The series of seventeen measurements was repeated every two months during the school year, in November, January, March, and May, not with the intention or hope of establishing bimonthly increments but by smoothing, to obtain the truest record of a child's size in each dimension at the measurement period nearest the midpoint of a year (2 years, 0 months, etc.). All statistical treatment of material is in year groups, no shorter intervals being significant for so small a number of cases. The age range in the groups is from 0 year, 6 months to 1 year, 5 months, etc., the midpoint thus falling at twelve, twenty-four, and thirty-six months.

*Roentgenograms.*—The worst thing about a measurement taken on the living child is the best thing about his roentgenogram. The material is permanent and can be checked at any time. It neither grows nor moves out of town. If it is a poor record, due to curved position of trunk or extremity, it can be eliminated, unlike the doubtful figures on the living which, six months too late for verification, confront the statistician. The difficulties arising from the necessity to correct for distortion, while serious and complicated for such parts of the body as the adult pelvis, are relatively simple in the extremities of children. The wrist and ankle lie on the plate so that the beam of rays passing through them is practically equivalent to the central ray and therefore no distortion is encountered in measurements at these points. A correction was worked out for the divergence of the rays, resulting in elongation of the image of arm and hand (40). All measurements on the roentgenograms were made by the writer. From 1924 to 1927, films of the City and Country School groups were made every three months. After the statistical analysis for a preliminary report (43) showed that the size and regularity of the increments did not require an interval of less than six months, roentgenograms were made only in November and May and variabilities in this final study are presented in both six and twelve month groups.

The amount of repetition of individuals in age groups for averages of ossification of the hands and for stature and weight has been tabulated for the New York and Merrill-Palmer material and is given below:

| | New York Private Schools | | | | Merrill-Palmer Nursery School | | | |
|---|---|---|---|---|---|---|---|---|
| Years | Number | Per cent | Number | Per cent | Number | Per cent | Number | Per cent |
| | Boys | | Girls | | Boys | | Girls | |
| 1 | 73 | 57 | 60 | 53 | 30 | 40 | 26 | 35 |
| 2 | 17 | 13 | 13 | 12 | 27 | 36 | 26 | 35 |
| 3 | 15 | 12 | 12 | 11 | 15 | 20 | 19 | 25 |
| 4 | 11 | 9 | 19 | 17 | 3 | 4 | 4 | 5 |
| 5 | 11 | 9 | 8 | 7 | | | | |

The individuals from the Horace Mann School and the Columbia Institute of Child Development explain the high percentage of one-group records in the New York table. About 25 per cent of the Iowa children (132 individuals) appear in more than one age group.

## TECHNIQUE AND MEASUREMENTS

The seventeen measurements taken on the main New York group (City and Country School) are listed below.

1. Weight
2. Height standing
3. Length reclining
4. Stem length (Crown—Rump)
5. Trunk length (Suprasternale—Pubes)
6. Shoulder breadth (Biacromial)
7. Pelvic breadth (Bicristal)
8. Upper arm length
9. Forearm and hand length

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10. Lower leg length (Tibiale—base of heel)
11. Span
12. Head breadth
13. Head length
14. Face height (Nasion—Gnathion)
15. Face height (Nasion—Prosthion)
16. Face breadth (Bizygomatic)
17. Lower jaw breadth (Bigonial)

All measurements were taken from anatomical points selected by the International Agreement for the Unification of Anthropometric Measurements (30). The projection technique—Hrdlicka (30), Martin (34)—also advocated by the agreement was not employed because it is ill adapted to young subjects. It is extremely difficult for a child of three to hold one posture long enough for the measurement of stature, and to maintain it throughout five or six other measurements whose validity depends on no shifts of legs, trunk, or shoulders is utterly impossible. Stature, in addition to the standing position with the stadiometer, was also measured while the child reclined on a board. Stem length and trunk length were taken in the same position. The segments of the extremities are direct measurements between two anatomical points with an anthropometer. Each measurement will be described in detail in the section devoted to its discussion.

The instruments used were scales graduated to twentieths of kilograms (Buffalo Scale Company), a stadiometer manufactured by the Narragansett Machine Company of Providence, an Alig and Baumgärtel anthropometer, Hrdlicka large sliding calipers, Colin small sliding calipers, Hermann spreading calipers, steel tape, and the board already mentioned. This board, built of hard maple, 141 cm. long externally, with a measuring surface 47 cm. wide, had end pieces and one side piece 11.5 cm high set at right angles. On the surface of the board at 4 cm. from each side were inserted rules calibrated in centimeters and millimeters. A portable square with handle was set against the right angled side piece and pressed against the heels or the ischia and the measurement (total length or stem length) read from both rules. The child's head rested against the upper end-piece. The board was used for the stature of all children under seven, and for the stem length of all children. While trunk length was taken with the anthropometer, the child remained reclining on the board.

In measuring roentgenograms, the anthropometer was used for total forearm length and the small sliding calipers for radius length, hand length, the transverse diameters of epiphyses and diaphyses of radius and tibia and the maximum shadow of the calcaneum.

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# CHAPTER II

## THE GROWTH OF THE BODY

### GROSS MEASURES

The mark on the bedroom wall and the scales at the corner drugstore are the most common anthropometric instruments. Their records, inaccurate and ephemeral, seldom reach paper, but the mass of figures on which most growth studies are based are limited to the same traits which interest the parents—height and weight. These two measurements of bulk are the most obvious, the simplest to take under all working conditions, and in their interrelationship, the easiest to misinterpret. Because a study of the significance of weight in its fluctuations and in relation to stature and to skeletal parts cannot be successfully carried on without control of diet and exact knowledge of constitutional type in the child's family lines, it is here considered only as an isolated measure. The failure of weight-for-height tables made from one racial or economic group to select the undernourished children of other groups is self-evident (21), and the use of the index even within the group on which it is based is further weakened when we see that the dimensions of the chest and pelvis correlate higher with weight than does stature (22). The conditions under which this study was carried on place its greatest value within the scope of skeletal development and leave outside all considerations of nutrition.

*Stature*

Stature measures the body as a whole both obviously and in a deeply significant manner. Tied closely to the total length of an individual are the other skeletal dimensions and, in a slightly less degree, the rate of ossification. This relationship is as close at one year of age as at eight. (See page 75.) In fact, it begins in the early fetal stage and persists in the adult (33, 45). Moreover, tallness and shortness of adult stature is present in the young child, and if strong factors of retardation or acceleration do not appear to change the natural course of growth, the individual, year by year, will maintain very nearly the same position in relation to his age, sex, race, and economic group. (See page 133.)

Professor Boas (11, 13) in a study of 120 boys from eleven years to adult has proved that short children will be on the average short adults and similar growth will characterize tall children. The stature of girls between seven and thirteen years, as Carolyn Adler[2] has recently found, has a positive relation between the initial measurement at seven and the onset of accelerated pubertal growth. The tallest children grow more rapidly from ten to eleven while the shorter children do not reach their period of marked increase until the ages of twelve and thirteen. From our own series, we have evidence that children show a high correlation between their first record of stature and that of one, two, or three years later, whether the initial measurement is made at two, three, four, five, or six years of age. It seems, then, that adult shortness and tallness may be established at a very early age.

Two measures of stature for the main New York group were made for each child over three years old, length reclining and height standing; for children under three, there is a record of length only. For height, the stadiometer was employed, the child standing erect with feet together and chin level. If two readings did not agree, a third was taken. Length was measured on the board already described (See page 21), the child's head resting directly but not pressed against the upper end-piece, arms at sides, and chin indicating neither ceiling nor sternum. A teacher from the nursery school held in position the heads of the youngest children. The square was laid firmly against the upright soles of the feet and the measurement read to the nearest millimeter from one scale by the writer and from the other by the assistant. Measurement was repeated until agreement was reached at two consecutive readings.

The lengths of the Merrill-Palmer School children were taken on the board described by Hejinian and Hatt (26). The apparatus and method of measuring statures of the Iowa group is the same as that instituted by Baldwin (3). A measuring board is used for the lengths of children under eighteen months; for all others, height is taken by the paper wall scale.

For children between the ages of three and eight years, length is almost invariably a larger measurement than height, the excess ranging from two millimeters to three centimeters. Height never exceeded length and only one case of exact coincidence was found.

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[2] Adler, Carolyn: Growth of Children from Four to Fourteen Years. At the Bureau of Educational Experiments, New York City. Unpublished Study.

The averages as indicated by the following tabulation of the individual differences do not change with increased age, nor do the deviations become much more uniform.

| Age, Years | Children | Mean Difference Boys | S. D. | Children | Mean Difference Girls | S. D. |
|---|---|---|---|---|---|---|
| 3 | 13 | +0.99 | 0.52 | 11 | +1.15 | 0.85 |
| 4 | 24 | +1.24 | 0.59 | 34 | +1.16 | 0.50 |
| 5 | 33 | +1.29 | 0.64 | 35 | +1.05 | 0.61 |
| 6 | 23 | +1.01 | 0.49 | 28 | +1.18 | 0.52 |
| 7 | | | | 16 | +0.89 | 0.45 |
| 8 | | | | 12 | +1.28 | 0.46 |

Conversion of individual measurements from length to height or vice versa for comparison with other data is, of course, impossible and on the basis of the small number of cases, a group correction did not seem justified.

The stature of the young private school children is presented on Tables 1 and 2. The five columns of these tables arranged in the manner followed throughout the book, are as follows: (1) age in years, the range being from zero years six months to one year five months and fifteen days, (2) the number of individual records, (3) the arithmetic average or mean, (4) the standard deviation or mean square deviation, which measures the variability of

TABLE 1

Stature (Length in Centimeters): Mean, Standard Deviation and Range for New York Private School and Merrill-Palmer Nursery School Children

| Age, Years | New York Private Schools | | | | Merrill-Palmer School | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Boys | | | | |
| 1 | 21 | 75.2 | 4.80 | 66— 84 | | | | |
| 2 | 24 | 89.9 | 3.46 | 80— 96 | 16 | 90.4 | 3.12 | 84— 96 |
| 3 | 36 | 97.1 | 3.94 | 89—103 | 40 | 96.5 | 3.90 | 85—104 |
| 4 | 35 | 102.7 | 5.53 | 92—111 | 49 | 102.7 | 3.52 | 94—112 |
| 5 | 35 | 112.1 | 4.53 | 98—122 | 32 | 108.7 | 3.02 | 102—115 |
| 6 | 26 | 116.7 | 4.63 | 104—124 | | | | |
| | | | | Girls | | | | |
| 1 | 15 | 75.4 | 5.28 | 64— 87 | | | | |
| 2 | 22 | 86.7 | 2.67 | 83— 92 | 8 | 86.8 | 3.38 | 86— 92 |
| 3 | 32 | 96.4 | 4.08 | 88—104 | 47 | 95.0 | 3.72 | 87—106 |
| 4 | 36 | 103.8 | 3.82 | 96—111 | 53 | 101.7 | 3.98 | 90—112 |
| 5 | 38 | 111.0 | 4.26 | 103—120 | 32 | 108.1 | 3.63 | 100—114 |
| 6 | 30 | 116.8 | 3.68 | 112—125 | | | | |

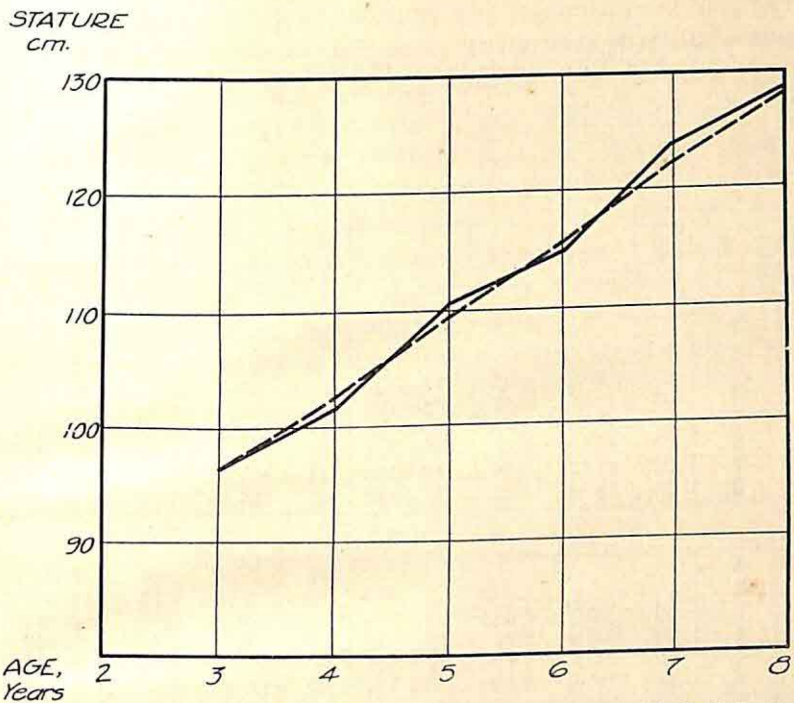

Figure 1. Stature (Height in Centimeters) for the New York Private School Children. Boys (———); Girls (- - - -)

the group, and (5) the range. About two-thirds of the cases should lie between plus and minus one unit of the standard deviation. For example (Table 2), the average height of fifty-one New York private school boys at five years of age is 110.4 centimeters. The standard deviation is 4.51. Therefore, about thirty-four cases or two-thirds of the boys have heights between 105.9 and 115 centimeters. The total range of heights is from 97 to 120 centimeters. If the standard deviation is small in relation to the mean, the trait measured shows a low degree of variation. The range is given on each table to show the extent of a trait in a group of normal children.

*Sex Differences.*—Between the ages of two and eight years, the stature of both boys and girls progresses at a fairly uniform rate. Throughout the age range the boys' stature is equal to or greater than the girls' (Tables 1 and 2, Figure 1). The one exception is the four-year-old groups from New York, which is due to sampling, the same reversal of the usual order appearing in the averages for

TABLE 2

Stature (Height in Centimeters): Mean, Standard Deviation and Range for New York Private School Children and Iowa Child Welfare Research Station

| Age, Years | New York Private Schools | | | | Iowa Child Welfare Research Station | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Boys | | | | |
| 1 | | | | | 48 | 74.1 | 4.79 | 63— 83 |
| 2 | | | | | 13 | 87.2 | 3.29 | 83— 92 |
| 3 | 23 | 96.2 | 4.89 | 88—107 | 20 | 95.5 | 2.82 | 91—101 |
| 4 | 38 | 101.5 | 5.11 | 91—109 | 25 | 102.6 | 3.98 | 94—108 |
| 5 | 51 | 110.4 | 4.51 | 97—120 | 28 | 110.2 | 3.91 | 103—117 |
| 6 | 35 | 114.9 | 5.10 | 103—122 | 40 | 115.4 | 4.14 | 106—127 |
| 7 | 23 | 123.7 | 4.36 | 117—135 | 44 | 121.0 | 4.67 | 111—134 |
| 8 | 18 | 128.6 | 6.25 | 117—142 | 47 | 127.6 | 5.36 | 115—139 |
| | | | | Girls | | | | |
| 1 | | | | | 29 | 70.0 | 4.70 | 62— 76 |
| 2 | | | | | 13 | 85.8 | 4.70 | 78— 94 |
| 3 | 25 | 96.2 | 3.90 | 88—104 | 25 | 96.0 | 4.55 | 85—106 |
| 4 | 41 | 102.7 | 3.72 | 96—111 | 31 | 101.5 | 3.84 | 94—108 |
| 5 | 49 | 109.7 | 4.73 | 103—118 | 38 | 108.7 | 4.37 | 99—123 |
| 6 | 39 | 115.6 | 3.38 | 111—124 | 40 | 114.7 | 3.56 | 105—120 |
| 7 | 23 | 122.1 | 5.25 | 115—132 | 36 | 119.9 | 5.61 | 110—130 |
| 8 | 15 | 128.1 | 5.44 | 121—138 | 30 | 124.0 | 5.38 | 114—134 |

weight, stem length, shoulder breadth, and pelvic breadth (Tables 4, 5, 15). The amount of sex difference is uneven from year to year in the different groups and is often negligible. It is most marked in the New York group at two years (3.2 cm.) and seven years (2.0 cm.), in the Merrill-Palmer children at two years (3 cm.), and the Iowa children at one year (4 cm.) and eight years (3.5 cm.). The general tendency, then, for boys to be slightly taller than girls between one and eight years of age is most marked at both ends of the scale. During the last two months of fetal life according to Schultz (47), the general size of the male is slightly greater than the female.

*Group Differences.*—Comparing the lengths of the New York and Detroit children (Table 1) and the New York and Iowa heights (Table 2), the correspondence between the groups is evident. The New York and Detroit boys have a practically identical average stature at two, three, and four years, and the excess of the New York group at five years is because the mean age of the

New York groups is 3.2 months older than the Detroit. The girls' averages, identical at two and close at three, diverge at four and five years in the same degree as they differ in age, the New York girls being the older and taller at both ages. Iowa and New York boys are of practically equal height until seven and eight years when the New York averages are 3 cm. and 2 cm. higher. The New York girls show a consistent excess of 1 cm. over the Iowa girls until seven and eight years when it increases to 2 and then to 4 cm. The average age of the Iowa groups is not known. These irregularities rising from sampling are insignificant when we compare them with the regular differences existing between the New York private school children (or the Detroit or Iowa groups for that matter) and averages based on children from less favored environments.

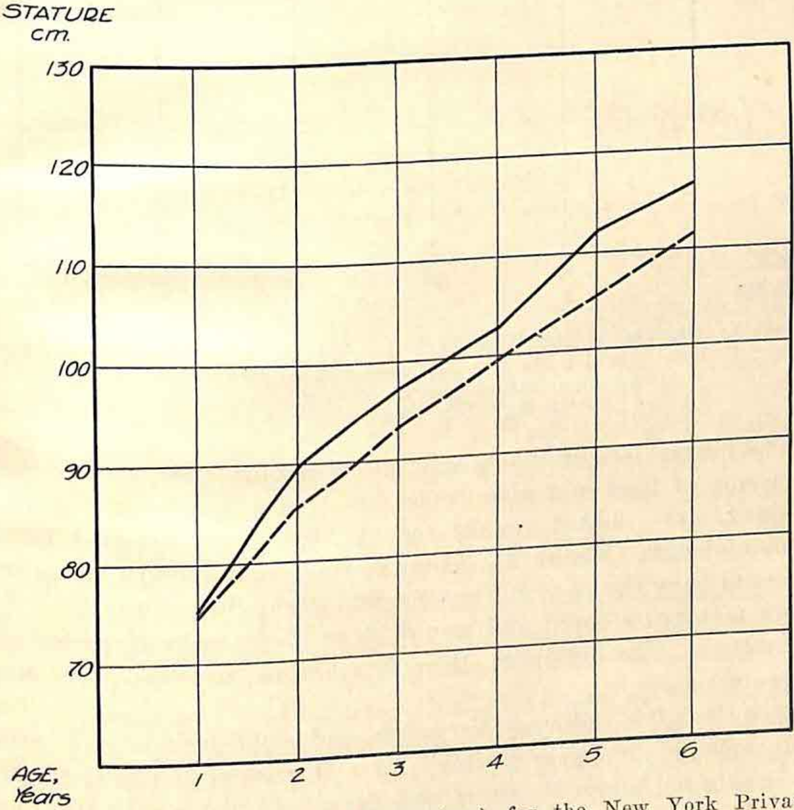

Figure 2. Stature (Length in Centimeters) for the New York Private School Boys (———) and the Woodbury Boys (- - - -)

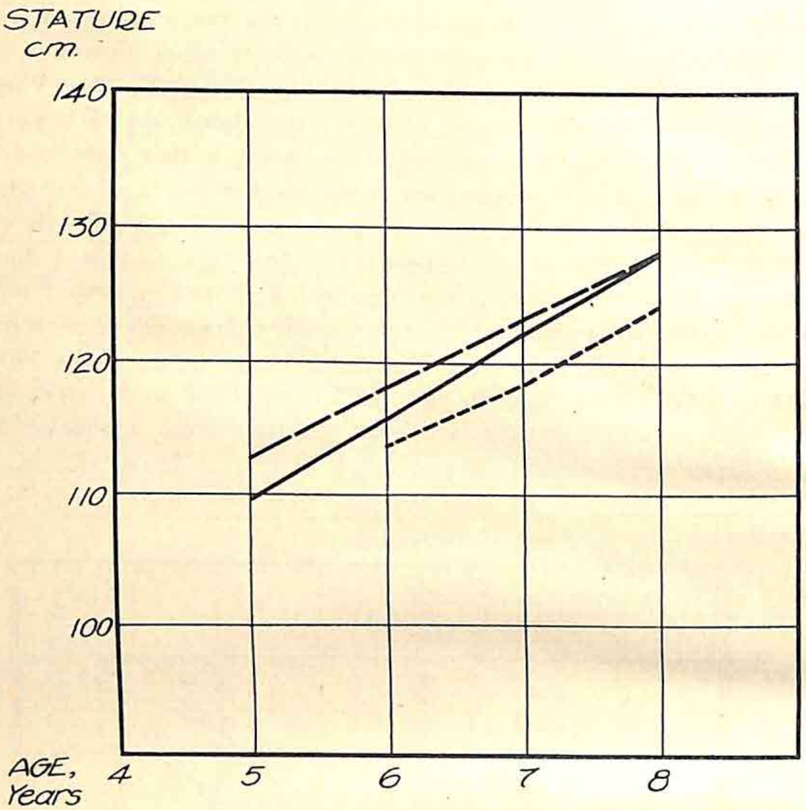

Figure 3. Stature of the New York Private School Girls (———), the Private School Girls (- - - -) measured by Gray, and Third Generation Native Born Children (— — — —) U. S. Public Health Service

The average statures published by Woodbury (58) from measurements of boys and girls under six years, in all parts of the country, were plotted against the averages from the New York table of length (Figure 2). Records made with tape measures in crowded baby clinics would not deviate consistently from the New York measuring board and would be as likely to be in excess as in arrears. The difference, then, is real and in accord with our expectations.

For the older children (six, seven, and eight years) more carefully selected data were available for comparison. A recent report of the United States Public Health Service (19) gives the statures of public school children from about thirty towns in four sections of the United States—Northeast, North Central, South Central, and Western. All children are of the third native born generation, with parents and all four grandparents born in the United States, thus eliminating many of the more recent short statured peoples present as ancestral factors in the New York private school group, only 56 per cent of which is pure third generation stock. According to the method of recording ages in the Public Health Series each group is probably older than the New York children. However, Figure 3 again illustrates the greater stature of individuals of better environment. A close correspondence exists between the New York boys and girls and the private school children measured by Dr. Horace Gray (23, 24, 25) as indicated by Figure 3 and the following tabulation:

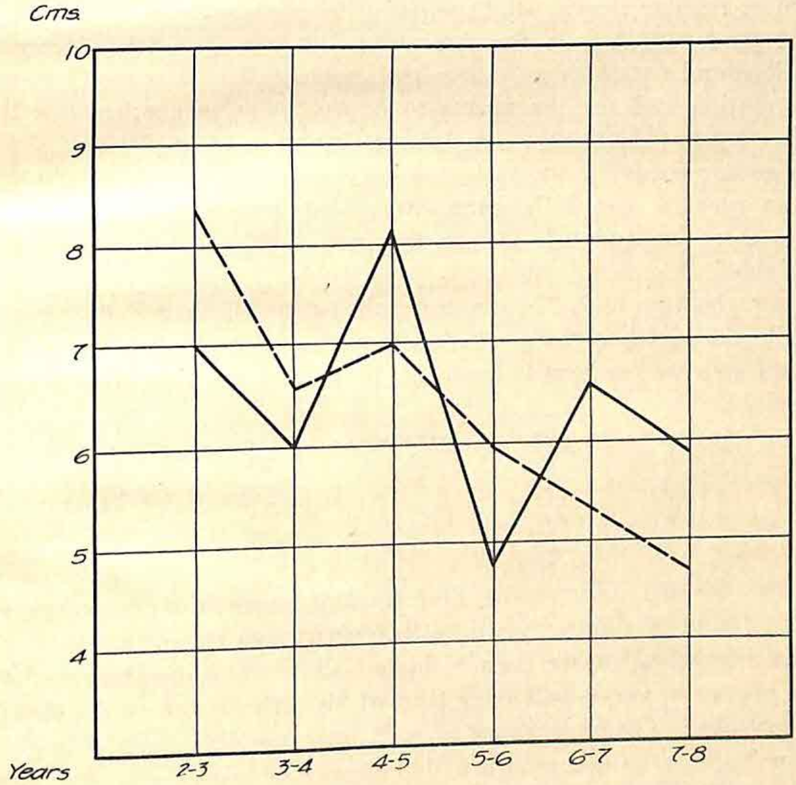

Figure 4. Increments of Stature for the New York, Merrill-Palmer, and Iowa Combined Groups. Boys (———), Girls (- - - -)

| Age, Years | Eastern | | Chicago | |
|---|---|---|---|---|
| | Children | Mean | Children | Mean |
| | Boys | | Girls | |
| 6 | 9 | 119.0 | 35 | 118.1 |
| 7 | 35 | 124.1 | 58 | 123.4 |
| 8 | 49 | 130.2 | 84 | 128.3 |

The ancestry of the boys from such eastern private schools as Groton, Middlesex, and Hill is assumed to be pretty generally American British. The racial stock of the girls from five private schools near Chicago was similar to the Eastern private school boys with a larger amount of Jewish stock.[3] By a very narrow and uneven margin, Gray's subjects still maintain their title of "The Tallest American Boys." Only at six years where he has nine cases is there a real difference in the means. Again, his boys are probably older than the New York group. The Chicago girls show a more regular though slight superiority to those from New York. The tendency then is for American children from the favored background found in private schools to be taller than the general population and for the means to approximate each other closely whatever may be the type or date of European racial derivation.

*Increments.*—The amount of annual gains in stature fluctuates from year to year with sharp alternations among the boys and a smoother rise and fall among the girls. Figure 4 presents the weighted increments calculated from Tables 1 and 2. As appears below, the boys make the greatest gain between four and five years while the girls' second peak comes at the same point. The minimum increase for boys is from five to six and for girls from seven to eight.

| Age, Years | Boys | Increments | Girls | Increments |
|---|---|---|---|---|
| 2 to 3 | 96 | 7.0 | 104 | 8.4 |
| 3 to 4 | 147 | 6.0 | 161 | 6.6 |
| 4 to 5 | 146 | 8.2 | 157 | 7.0 |
| 5 to 6 | 101 | 4.8 | 109 | 5.9 |
| 6 to 7 | 82 | 6.6 | 77 | 5.3 |
| 7 to 8 | 73 | 5.9 | 50 | 4.7 |

The decided peak at five and one-half years which Davenport (20) found in a curve based on 2,000,000 cases he considered rose from statistical rather than biologic causes. The sampling under six years was very small since most of his series began at the usual school age. The appearance of such a peak a little earlier in the New York and Iowa groups of both boys and girls, each of which is a continuous age series from one to eight years, would suggest a more vital explanation which might be extended to include the rise between two and three years, and possibly also between seven and eight.

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[3] Gray, Horace, and Ayres, J. G.: Growth in private school children. Chicago, Ill.: The University of Chicago Press, 1931. (In preparation.)

The significance of these fluctuations lies in their sex difference and in their relation to the same process in other parts of the body. That gains in weight in identical groups should follow a very similar course to stature is at least partially predictable because of common elements, but it is more surprising to find in a selection of one-fifth to one-seventh of the number of individuals, the same rise and fall at the same points for the transverse breadths of the trunk (Figures 4, 8, 13, 14). The greatest annual increment of weight, shoulder breadth, and pelvic breadth of boys between two and eight occurs between four and five years of age just as it does in stature and the similarity of the four diagrams throughout is marked. The female gains, particularly in pelvic breadth and weight, show the character just indicated in the case of stature of progressing regularly from four to eight years and appear nearly horizontal on the graphs. Here we have an illustration of the tendency appearing frequently though irregularly throughout the study for the female to be less variable than the male. The basic relationship of all parts of the body to the total stature emerges even more clearly. The theory that the transverse diameters make their greatest increase in years alternate to the vertical does not seem tenable. On the basis of the small number of cases obtained for certain parts of the body, these findings are definite indications rather than final conclusions.

That time of year does not affect increments of stature and therefore a large proportion of spring or winter measurements in any age group would not emphasize or weaken the expected gain is shown by Table 3. The two six-month intervals between the first and last measurement periods of the school year give uniform averages and the three two-month intervals during the term are also of practically equal size. This is in accord with recent belief that under good environmental conditions there is no real seasonal variation in the amount of a child's growth.

Stature as the fundamental trait with which most bodily dimensions tend to harmonize has been already frequently stressed. The proof will be presented as each segment is discussed and the complete relationship table is given at the close of the chapter devoted to the growth of the body (page 75). The correspondence between the eruption of permanent dentition and stature has also been established (page 132). The statistical tools used are the coefficients of correlation and regression. The determination that in fetal life the growth of each external dimension is directly proportional to the absolute growth of body-length is, in the opinion of Scammon and Calkins (45), the most important conclusion reached in their recent study. The straight line relationship is represented by analytic expressions determined from the averages of each dimension for five cm. intervals of total length. By coefficients of correlations, Lundborg and Linders (33) have shown that the same type of relationship exists in a group of 47,000 adult males.

TABLE 3

Seasonal Increments of Stature and Weight (in Centimeters and Kilograms): Mean and Standard Deviation for New York Private School Children

| Months | Boys | | | Girls | | |
|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Children | Mean | S. D. |
| | | Stature | | | | |
| November to May | 57 | 3.70 | 1.20 | 61 | 3.60 | 0.41 |
| May to November | 55 | 3.50 | 1.35 | 52 | 3.40 | 0.92 |
| November to January | 57 | 1.40 | 0.50 | 59 | 1.30 | 0.68 |
| January to March | 58 | 1.20 | 0.50 | 53 | 1.10 | 0.61 |
| March to May | 60 | 1.10 | 0.67 | 56 | 1.20 | 0.54 |
| | | Weight | | | | |
| November to May | 50 | 0.97 | 0.49 | 53 | 1.20 | 0.63 |
| May to November | 55 | 0.98 | 0.57 | 53 | 0.99 | 0.56 |
| November to January | 60 | 0.40 | 0.47 | 58 | 0.30 | 0.42 |
| January to March | 60 | 0.32 | 0.39 | 55 | 0.52 | 0.41 |
| March to May | 62 | 0.34 | 0.45 | 57 | 0.38 | 0.40 |

Considered as an isolated measure, the average stature of young children has an economic or environmental significance which masks European race distinctions. The absolute amount of its annual progress seems to rise and fall in alternate years. The season does not affect the amount of increment. The sex difference in adult stature appears largely as a tendency for boys to be taller than girls between the ages of two and eight years.

*Weight*

The weight of a child, even more than his stature, would seem to depend upon his economic stratum. Since our equipment was

TABLE 4

Weight (*in Kilograms*): Mean, Standard Deviation and Range for Children from the New York Private Schools, Merrill-Palmer Nursery School and the Iowa Child Welfare Research Station

| Age, Years | New York Private Schools | | | | Merrill-Palmer Nursery School | | | | Iowa Child Welfare Research Station | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | | Boys | | | | | | | |
| 1 | 20 | 10.5 | 1.78 | 8—14 | | | | | 48 | 9.7 | 1.54 | 6—14 |
| 2 | 25 | 13.3 | 1.65 | 9—16 | 15 | 13.4 | 0.85 | 11—15 | 13 | 12.9 | 0.95 | 10—14 |
| 3 | 40 | 15.1 | 1.43 | 13—19 | 40 | 15.0 | 1.63 | 11—18 | 20 | 15.3 | 1.15 | 13—18 |
| 4 | 39 | 16.6 | 1.81 | 12—21 | 48 | 16.5 | 1.24 | 13—19 | 25 | 16.8 | 1.87 | 12—20 |
| 5 | 51 | 19.0 | 2.07 | 15—22 | 33 | 18.5 | 1.65 | 15—22 | 28 | 19.0 | 1.99 | 16—23 |
| 6 | 35 | 20.3 | 2.23 | 15—24 | | | | | 40 | 20.5 | 2.03 | 16—25 |
| 7 | 23 | 23.6 | 2.98 | 20—29 | | | | | 44 | 23.1 | 3.09 | 19—33 |
| 8 | 18 | 26.0 | 4.23 | 20—38 | | | | | 47 | 25.6 | 3.21 | 21—34 |
| | | | | | Girls | | | | | | | |
| 1 | 14 | 10.2 | 1.27 | 7—13 | | | | | 29 | 8.4 | 1.40 | 6—12 |
| 2 | 22 | 12.4 | 1.15 | 10—15 | 8 | 12.2 | 1.09 | 10—14 | 13 | 12.4 | 1.74 | 10—15 |
| 3 | 34 | 14.7 | 1.20 | 13—18 | 48 | 14.5 | 1.43 | 10—18 | 25 | 14.8 | 1.75 | 11—15 |
| 4 | 41 | 17.3 | 1.91 | 14—22 | 53 | 16.0 | 1.70 | 12—19 | 31 | 15.9 | 1.52 | 12—18 |
| 5 | 48 | 18.9 | 1.77 | 14—22 | 32 | 18.3 | 1.74 | 15—22 | 38 | 18.1 | 1.98 | 15—25 |
| 6 | 39 | 21.1 | 2.08 | 17—26 | | | | | 40 | 20.4 | 2.01 | 15—23 |
| 7 | 23 | 23.9 | 2.49 | 21—39 | | | | | 36 | 22.7 | 3.94 | 17—39 |
| 8 | 15 | 26.8 | 2.12 | 23—30 | | | | | 30 | 24.0 | 3.35 | 18—31 |

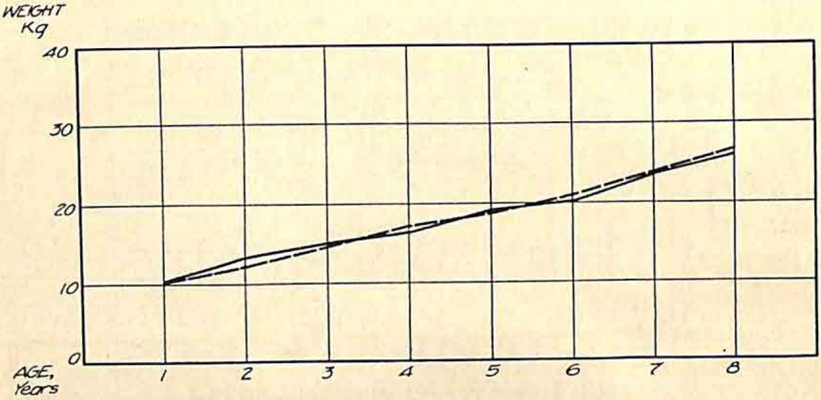

Figure 5. Weight (in Kilograms) of the New York Private School Children. Boys (———) and Girls (- - - -)

not adapted to the study of nutrition or the endocrine glands, the discussion of weight will be limited to social differences and to age and sex characteristics.

Scales graduated to twentieths of kilograms were used to weigh the children. All weights, with the exception of those of a few babies under twenty-four months were taken in the nude; clothing equal to that worn by each baby was weighed and subtracted. All weights were recorded in kilograms and tenths of kilograms.

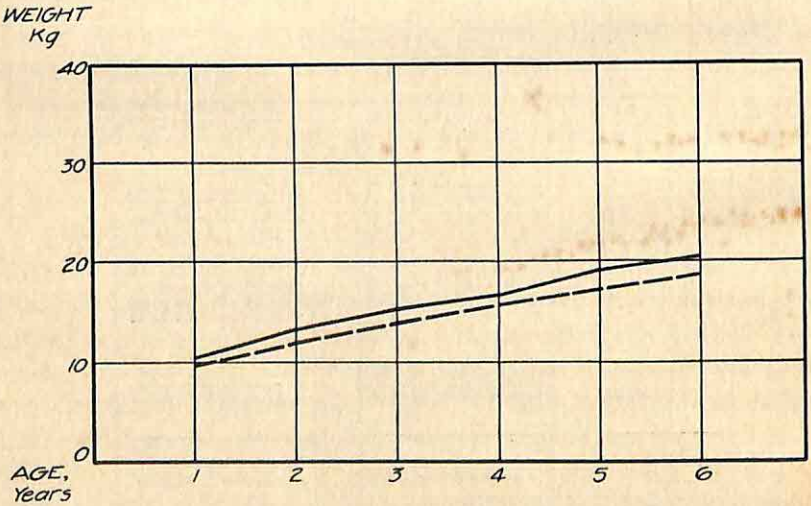

Figure 6. Weight (in Kilograms) for the New York Private School Boys (———) and the Woodbury Boys (- - - -)

From one to eight years of age, boys usually have an average weight slightly in excess of girls. This runs from a half kilogram to a kilogram and a half. There is often exact coincidence (Table 4). In the New York group alone the girls are slightly heavier than the boys at four, six, and eight years (Figure 5).

The weights of the three private school groups (New York, Merrill-Palmer, Iowa) correspond in much the same way as do their statures. The boys are extremely close, the three groups having practically identical averages between two and five years. The Merrill-Palmer decline at five is again to be explained by the fact that the average age is more than three months younger than that of the New York group. At one, seven, and eight years, the New York boys are somewhat heavier than the Iowa boys. The Iowa girls are decidedly lighter than those from New York with the exception of two and three years. Merrill-Palmer averages are nearer those from Iowa than from New York. In percentage

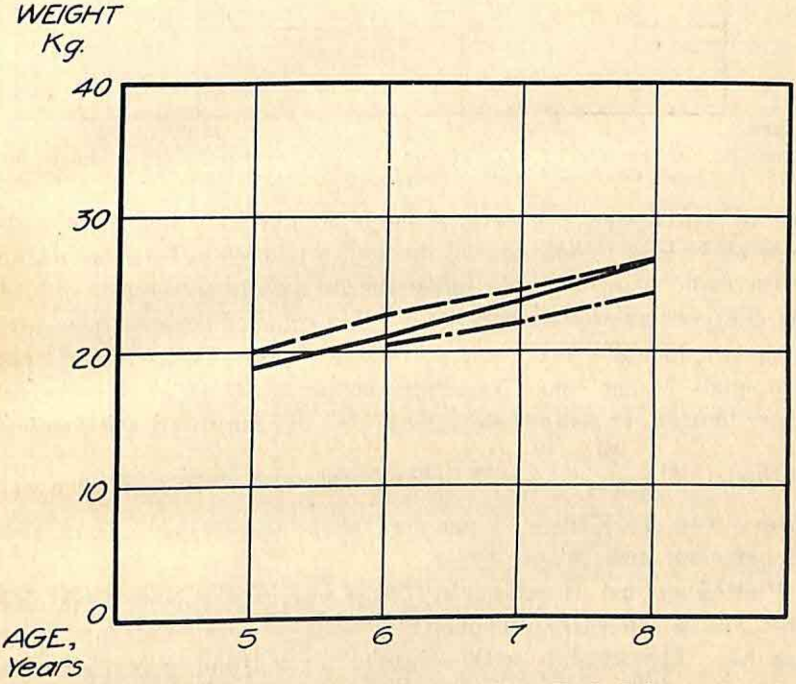

Figure 7. Weight (in Kilograms) for the New York Private School Girls (———), the Private School Girls measured by Gray (- - - -), and the Third Generation Native Born Girls (— · — · — ·) U. S. Public Health Service

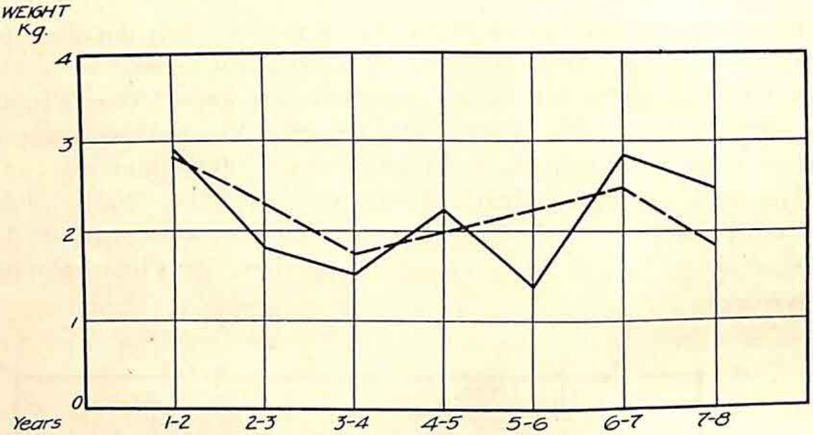

Figure 8. Increments of Weight for the New York, Merrill-Palmer and Iowa Combined Groups. Boys (———), Girls (- - - -)

rate of increase as well as in absolute weight, the New York girls show their lead. Computation began at two years because, owing to the rapid monthly rate during the first eighteen months of life, the one year averages mean little. Percentage increases in weight from two to eight years are as follows: New York boys 65 per cent, girls 74 per cent; Iowa boys 66 per cent, girls 64 per cent. These figures are computed by Brody's (16) improved arithmetical method $(100 \frac{W_2-W_1}{\frac{1}{2}(W_1+W_2)})$. The increase of stature is more uniform: New York boys 35 per cent, girls 38 per cent; Iowa boys 38 per cent, girls 36 per cent.

Plotted against Woodbury's (58) averages, the New York children are as consistently above them as they were in stature (Figure 6). The kinship with other children from very favorable environments is again established by Figure 7. The children are the same as in Figure 3, Gray's (23, 24) private school series and the third generation native born public school children weighed by the United States Public Health Service (19).

Annual increments of weight, as indicated by the following tabulation like those of stature, have alternate years of greatness,

| Age, Years | Boys | Increments | Girls | Increments |
|---|---|---|---|---|
| 1 to 2 | 38 | 2.9 | 35 | 2.8 |
| 2 to 3 | 100 | 1.8 | 107 | 2.3 |
| 3 to 4 | 112 | 1.5 | 125 | 1.8 |
| 4 to 5 | 112 | 2.2 | 118 | 2.0 |
| 5 to 6 | 75 | 1.4 | 79 | 2.2 |
| 6 to 7 | 67 | 2.9 | 59 | 2.5 |
| 7 to 8 | 65 | 2.5 | 45 | 1.8 |

the peaks rising between four and five and seven and eight (Figure 8). The girls show again a more even development.

No seasonal differences in amount of weight gained were found among the New York children. The increments of weight conform closely to those of stature in illustrating the absence of seasonal influence on the increase of bulk (Table 3).

### THE TRUNK

Around the human trunk (with or without head) have centered many scientific storms. The two usual measurements, stem-length (sitting height, crown-rump length) and trunk length between the bony landmarks of the suprasternal notch and the pubic symphysis, have furnished material for numerous studies of age, sex, race, and evolutionary significance. The index of sitting height and stature is commonly used as a criterion of constitutional type, and the steady decrease with age and the adult sex difference for all races are well known. Trunk length in relation to arm length and to the breadth of shoulders and pelvis has formed the basis of various phylogenetic investigations among primates of high and low degree.

TABLE 5

Stem Length: Mean, Standard Deviation and Range in Centimeters of New York Private School and Merrill-Palmer School Children

| Age, Years | New York Private Schools | | | | Merrill-Palmer School | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Boys | | | | |
| 1 | 15 | 48.5 | 2.25 | 44—52 | | | | |
| 2 | 12 | 54.2 | 2.08 | 51—57 | 16 | 55.0 | 1.99 | 52—59 |
| 3 | 25 | 57.1 | 2.93 | 51—63 | 40 | 57.4 | 2.19 | 51—60 |
| 4 | 23 | 58.7 | 3.38 | 53—64 | 49 | 59.8 | 2.04 | 56—64 |
| 5 | 26 | 63.2 | 2.39 | 58—68 | 52 | 62.3 | 1.79 | 59—66 |
| 6 | 20 | 65.2 | 2.19 | 61—70 | | | | |
| 7 | 22 | 68.2 | 2.36 | 64—73 | | | | |
| 8 | 14 | 69.2 | 1.80 | 65—75 | | | | |
| | | | | Girls | | | | |
| 1 | 5 | 44.7 | 2.71 | 41—47 | | | | |
| 2 | 15 | 51.8 | 1.35 | 49—54 | 8 | 53.0 | 2.12 | 50—56 |
| 3 | 28 | 56.2 | 2.08 | 52—60 | 48 | 56.4 | 2.23 | 52—62 |
| 4 | 24 | 59.3 | 2.28 | 55—63 | 52 | 58.9 | 2.57 | 52—64 |
| 5 | 19 | 62.6 | 1.91 | 58—66 | 32 | 61.6 | 1.99 | 59—66 |
| 6 | 26 | 65.0 | 2.08 | 62—69 | | | | |
| 7 | 22 | 67.5 | 2.85 | 63—72 | | | | |
| 8 | 12 | 70.1 | 3.02 | 65—74 | | | | |

To follow these changes during the growth of young children, both stem length and trunk length were measured on the New York children. Stem lengths were also secured from the Detroit records, taken on the measuring board and by methods recently described (26). The stem lengths of the New York children were taken on our measuring board with head in the same position as for stature reclining, thighs flexed and legs held upward, and the square pressed until it reached the bones of the ischia. Care was taken to maintain the vertex against the end piece of the board without pushing against it. Children of all ages were measured by this method, the heads of the youngest being held in place by parent or guardian. Stem lengths were read and checked as they were for stature. Trunk lengths were taken while the child still reclined on the board but with the head no longer against the end piece. The long side of the board and the two parallel rules between which the child lay served as a guide to the symmetry of his position. The anthropometer was held against the upper border of the sternum and the upper border of the symphysis pubis in the middle line of the body. The measurement was repeated at least three times and recorded to the nearest millimeter.

### *Stem Length*

Stem length shows a large increment between one and two years of age (Table 5). Thereafter, the difference between the averages of each year group is from 4.5 to 1 cm. for the New York children and 3.5 to 2.4 cm. for the Detroit groups. The size of the New York samples is much less than for stature and weight. The average lengths from the two private schools, for both boys and girls, are extremely close.

The boys' stem length tends always to be greater than the girls'. The Merrill-Palmer girls have consistently shorter stems; the New York girls' are longer at four, the age at which they surpass the boys in a number of traits (See page 25) and also at eight years. Trunk length, however, with the exception of two years where the samples are less than ten, is quite without sex difference (Table 7).

The proportion of stem to total stature is of considerable descriptive value. This index $\left(\frac{\text{stem x } 100}{\text{stature}}\right)$ ranges from 73.0 for the white fetus at the third month to 48.9 for adult males from certain parts of Africa. Tall peoples have lower indices because leg length

TABLE 6

Stem-Stature Index: Mean, Standard Deviation and Range of New York and Merrill-Palmer Schools

| Age, Years | New York Private Schools | | | | Merrill-Palmer School | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Boys | | | | |
| 1 | 15 | 63.6 | 1.23 | 67—62 | | | | |
| 2 | 10 | 60.8 | 1.92 | 62—59 | 16 | 60.9 | 1.05 | 63—59 |
| 3 | 19 | 58.8 | 1.29 | 61—55 | 40 | 59.5 | 1.28 | 62—57 |
| 4 | 17 | 57.6 | 1.22 | 60—54 | 49 | 58.2 | 1.11 | 61—56 |
| 5 | 26 | 56.4 | 1.11 | 59—54 | 32 | 57.3 | 0.88 | 59—55 |
| 6 | 20 | 55.7 | 1.42 | 59—54 | | | | |
| 7 | 22 | 54.8 | 1.06 | 57—52 | | | | |
| 8 | 13 | 54.4 | 1.29 | 57—53 | | | | |
| | | | | Girls | | | | |
| 1 | 5 | 62.8 | 1.39 | 64—60 | | | | |
| 2 | 14 | 60.2 | 1.63 | 63—58 | 8 | 61.1 | 0.80 | 63—60 |
| 3 | 24 | 58.4 | 1.00 | 60—57 | 47 | 59.5 | 1.37 | 64—56 |
| 4 | 23 | 56.7 | 1.05 | 59—54 | 52 | 58.0 | 1.18 | 60—53 |
| 5 | 19 | 55.9 | 0.96 | 57—54 | 32 | 57.0 | 0.93 | 59—54 |
| 6 | 26 | 55.7 | 1.10 | 58—54 | | | | |
| 7 | 22 | 55.0 | 1.10 | 57—53 | | | | |
| 8 | 13 | 54.7 | 1.10 | 57—54 | | | | |

bears a closer relationship to stature than does trunk length (pages 42 and 75). From the early fetal months to birth, the stem decreases 6 per cent in proportion to the total body length (47). Between one and eight years, the legs claim another 10 per cent, and from the eight-year-old New York children to the adult Old Americans less than 2 per cent of maturity must be travelled (31). Table 6 gives an annual decrease of 1 per cent from three to seven years. The earlier decrease is about 2 per cent and between seven and eight, it is less than 0.5 per cent. The index at birth is, according to Scammon and Calkins (45), 67, 64 at one year and 54 at eight years (New York boys) and 53 for the 247 adult American males measured by Dr. Hrdlicka (31). Between the Old American men and women, there is a difference of 1 per cent, the average for 210 females being 53.9. This difference is characteristic of thirteen of the twenty racial and national groups listed by Martin (34). No evidence of the relatively shorter trunk length of the male is apparent before eight years (Table 6 and Figure 9). In fact, between one and five years, the New York boys have a slightly higher index than the girls. The Merrill-Palmer children of both

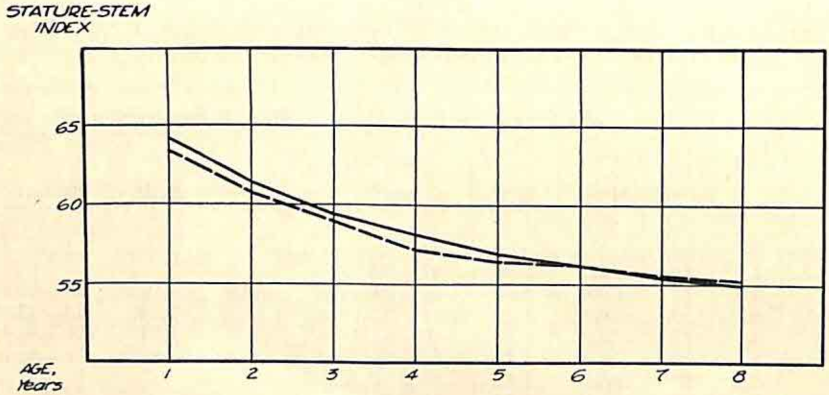

Figure 9. Stature—Stem Index for the New York Private School Boys (———) and Girls (- - - -)

sexes have practically identical averages. In four groups from childhood to adult published by Martin (34), (two American, Russian, Jewish, and Filipino), the girls' index first rises consistently above the boys' from ten to thirteen years. Among Munich school children from six to eleven and one-half years, the index for males after nine years is the smaller but never by more than 0.5 per cent.

Although the stem-stature index grows steadily smaller during childhood, it does not constitute a criterion of maturity for rating the individual. The annual average decrease is very small, the variability relatively high and the range considerable. The reason is obvious when we consider the connection between stature and leg-length. When adults of a racial group are ranged according to height, the stem-stature index decreases about 1 per cent with every ten centimeters of stature (Martin, 34). In childhood (two to eight years) the stem-stature index decreases annually about 1 per cent while stature increases about six or seven centimeters. The correlation between leg length and stature is as high among children as among adults (coefficient for New York children +.87, for 47,000 Swedish males twenty-one years of age +.87) and since an individual child tends to maintain his group rank in stature from year to year, there is obviously a large constitutional factor influencing the stem-stature index during the growth period. Further evidence is furnished by Hejinian and Hatt (26) who found that from two to five years of age, 72 per cent of the Mer-

TABLE 7

Trunk Length: Mean, Standard Deviation and Range in Centimeters for the New York Private School Children

| Age, Years | Children | Mean | S. D. | Range |
|---|---|---|---|---|
| | | Boys | | |
| 2 | 6 | 29.2 | 1.86 | 27.0—31.5 |
| 3 | 16 | 30.7 | 1.68 | 28.1—33.7 |
| 4 | 15 | 32.0 | 1.86 | 28.6—35.2 |
| 5 | 23 | 34.4 | 1.51 | 31.4—37.6 |
| 6 | 19 | 35.5 | 1.32 | 33.2—37.9 |
| 7 | 21 | 37.3 | 1.69 | 34.4—40.8 |
| 8 | 14 | 38.6 | 1.68 | 35.8—41.6 |
| | | Girls | | |
| 2 | 9 | 27.4 | 1.20 | 25.2—29.3 |
| 3 | 11 | 30.9 | 0.91 | 29.0—32.7 |
| 4 | 21 | 32.3 | 1.48 | 29.9—35.8 |
| 5 | 19 | 34.3 | 1.32 | 32.5—36.5 |
| 6 | 26 | 35.6 | 1.48 | 33.4—38.1 |
| 7 | 20 | 37.1 | 1.63 | 34.2—40.0 |
| 8 | 12 | 39.1 | 1.68 | 35.5—41.6 |

rill-Palmer children maintained their index in approximately the same percentile rank.

The stem-stature index then decreases annually during the growth period for two interlocking reasons, because with maturity a child's legs grow relatively longer and because each year he grows taller. The taller children at each age will tend to have a lower index than the shorter children and individuals will generally conform to the same body type from year to year. Young boys and girls have equal average proportions; there is no great difference between the children from Detroit and from New York. The value of the index as a descriptive method is considerable but as a standard of maturity it is very slight.

*Trunk Length*

Trunk length from suprasternal notch to pubic symphysis, the second measure of the upper body segments, is closely related to stature (Table 7). Because it is a direct diameter between two bony landmarks, it was selected rather than the composite stem length for correlation with stature. The spurious element inherent when a part is correlated with the whole was removed by relating the individual's trunk length to his stature minus trunk length. The formula used is that employed throughout the study, the

TABLE 8

Correlations of Trunk Length and Stature, Leg Length and Stature and Radius and Stature for the New York Children

| Age, Years | Trunk Length and Stature | | Leg Length and Stature | | Radius and Stature | |
|---|---|---|---|---|---|---|
| | Children | Correlation | Children | Correlation | Children | Correlation |
| | | | Boys | | | |
| 1 | | | | | 18 | +.82 |
| 2 | | | | | 19 | +.96 |
| 3 | 15 | +.79 | 14 | +.88 | 29 | +.74 |
| 4 | 15 | +.68 | 16 | +.85 | 33 | +.86 |
| 5 | 23 | +.71 | 26 | +.91 | 32 | +.80 |
| 6 | 19 | +.26 | 18 | +.92 | 24 | +.81 |
| 7 | 21 | +.53 | 22 | +.76 | 21 | +.86 |
| 8 | 14 | +.66 | 14 | +.91 | 16 | +.91 |
| All Groups | 107 | +.60 | 110 | +.87 | 192 | +.84 |
| | | | Girls | | | |
| 1 | | | | | 11 | +.91 |
| 2 | | | | | 21 | +.72 |
| 3 | 11 | +.51 | 11 | +.86 | 30 | +.87 |
| 4 | 20 | +.83 | 21 | +.82 | 34 | +.88 |
| 5 | 19 | +.53 | 20 | +.79 | 34 | +.72 |
| 6 | 25 | +.50 | 23 | +.58 | 28 | +.83 |
| 7 | 21 | +.80 | 22 | +.53 | 22 | +.86 |
| 8 | 13 | +.73 | 12 | +.75 | 15 | +.87 |
| All Groups | 109 | +.65 | 109 | +.70 | 195 | +.82 |

difference method which is an adaptation of the Pearsonian coefficient worked out as

$$r = \frac{\sigma^2 x + \sigma^2 y - \sigma^2 x\text{-}y}{2\sigma\ x\ \sigma y}$$

The justification of the use of correlation in small groups is found in the results (Table 8). All coefficients are positive and, with the exception of one group, show a marked or high degree of association. The standard deviations on which the correlation formula is based remain nearly uniform for each trait throughout the different age groups. Naturally, with so small a number of cases, a coefficient for a single group of +.79 cannot be considered more significant than one of +.53. When each group correlation is weighted by multiplying it by the number of cases and the sum divided by the total number, the obtained coefficients of +.60 for the boys and +.65 for the girls express fairly the relationship between stature and trunk length from three to eight years of age.

There is no trend of increasing or decreasing interdependency as the child grows older and no sex difference in the relationship. The coefficient obtained by Lundborg and Linders (33) from Swedish adult males is +.50, a further indication that final types begin early, and that at all ages, the growth of the trunk is somewhat proportionate to stature.

The proportion of trunk length to arm length and shoulder and pelvic breadth as indices of maturity or of evolutionary status will be discussed later.

## THE EXTREMITIES

The age changes in proportions of the upper and lower extremity are most difficult to follow at the time of their greatest interest. The slight development of the landmarks for measurement at shoulder, elbow, hip, and knee inevitably brings about small fluctuating deviations not serious perhaps in absolute diameters but responsible for rise and fall in ratios which affect reliable interpretation. The problem can be simply but expensively solved by the substitution of radiology for anthropometry. For only two segments of the upper extremity was this method available in the present study and on the reliability of those records rests our greatest sense of security.

### *The Lower Extremity*

There are two sources of information concerning the size of the lower extremity of the New York children. By subtracting stem-length from stature, a rough estimate of leg length can be deduced. The resulting figure for an individual of our series is from 10 to 15 per cent shorter than the actual measurement from the anterior superior iliac spine to the heel minus a constant correction of 15 mm. representing the distance from the iliac spine to the acetabulum. For two main reasons this direct measurement was not continued after a year's trial. The leg length used in a study of proportional changes over a period of years must be consistent from beginning to end and on very young children, direct measurement is not practicable, and the constant 15 mm. given by Martin, an artificial device at best, does not seem equally applicable throughout the 40 cm. range of stature from two to eight years of age (34), page 165).

In addition to the estimate of total length by subtracting stem from stature, the diameter from the tibial head to the base of the heel was measured. The child sat on the measuring board with legs swinging over the edge of the table so that they could be easily flexed at the knee in the anthropometrists' hunt for tibiale. To that often elusive point, the upper border and edge of the inner tuberosity of the head of the tibia, one branch of the large sliding calipers was applied, while on the second, the fixed branch, the base of the heel was held squarely.

The New York boys and girls have lower legs of practically equal length between two and eight years of age (Table 9). At three, the girls' legs are longer by 1 cm. and the boys show the same difference at one and at seven years.

The relative amount of growth during the period of this study is 44 per cent for the boys and 49 per cent for the girls, equal to the rate from birth to two years which, calculated from Scammon's (45) figures, is about 40 per cent. From two to eight years, the trunk of the New York private school children increases only 28 per cent, while the increments of the upper arm and of the radius within the same time limit, again rise to 44 per cent and 46 per cent. This difference in growth rate between the trunk and the extremities is a continuation in postnatal life of the "law of developmental direction" which governs the progress of embryo and fetus. The development of the vertebrate embryo tends to

TABLE 9

Lower Leg Length: Mean, Standard Deviation and Range in Centimeters for the New York Private School Children

| Age, Years | Children | Mean | S. D. | Range |
|---|---|---|---|---|
| | | Boys | | |
| 2 | 7 | 24.3 | 1.25 | 22.4—26.6 |
| 3 | 15 | 26.3 | 1.49 | 23.4—28.9 |
| 4 | 16 | 28.7 | 1.73 | 24.3—31.5 |
| 5 | 26 | 31.6 | 1.86 | 25.5—34.1 |
| 6 | 20 | 33.4 | 1.82 | 28.4—35.9 |
| 7 | 22 | 36.2 | 1.50 | 33.7—40.0 |
| 8 | 14 | 37.8 | 2.17 | 33.9—43.0 |
| | | Girls | | |
| 2 | 9 | 22.9 | 0.89 | 22.1—25.2 |
| 3 | 11 | 27.3 | 1.15 | 25.4—28.9 |
| 4 | 22 | 29.4 | 1.40 | 27.0—32.1 |
| 5 | 21 | 31.8 | 1.54 | 27.9—34.4 |
| 6 | 26 | 33.2 | 1.48 | 29.9—36.0 |
| 7 | 22 | 35.2 | 1.84 | 32.8—38.9 |
| 8 | 12 | 37.6 | 1.78 | 34.7—40.4 |

progress from head to heels. Scammon and Calkins found that for fetuses grouped at 5 cm. intervals of body length, the more proximal parts of the body made a larger amount of growth in the first 5 cm. interval of increased length than they did in the second or any succeeding 5 cm. interval ((45), page 270). Moreover, they have shown quantitatively that "the dimensions of the trunk show a graduation, those of the upper part have grown more with respect to body-length in the embryonic than in the fetal period and therefore undergo a decrease in relative size in the latter; those in the middle portion have grown at approximately the same rate in respect to total body-length in both periods and maintain a constant ratio to the total body-length; while those of the lower portion have grown less with respect to total body-length in the embryonic period than in the fetal period and gain in size relative to body-length in the latter epoch of prenatal life." ((45), page 268) Working with time intervals in early postnatal life, we find the same tendency persisting. The trunk, having completed a greater proportion of its final growth in the embryonic and fetal periods and the first two postnatal years gains 28 per cent during the next six years, while the upper arm gains 44 per cent, the radius 46 per cent, and the leg 47 per cent.

The close and consistent relationship which leg length bears to stature is clearly brought out in the correlations of Table 8. As in the correlations of stature and trunk length, the spurious element has been removed by associating leg length with the remainder when it has been subtracted from stature. The weighted and averaged group correlations, +.87 for boys and +.70 for girls, indicate a higher degree of relationship than the +.60 and +.65 obtained for stature and trunk length and this is borne out by the figures from thousands of adult males given by Lundborg and Linders (33), +.87 for stature and leg length and +.50 for stature and trunk.

### *The Upper Extremity*

The three main segments of the upper extremity were recorded by direct measurement and by roentgenograms. The upper arm from the New York series was obtained on the children. The arm was held extended forward, the elbow lightly flexed during the process of finding the distal end of the humerus at the radial articulation, and the diameter then measured with the anthropometer from that point to the superior and external border on the acromion process. At the same time, the forearm and hand was measured from the proximal end of the radius to the tip of the middle finger, the arm held straight forward at shoulder level. These measurements were made during the three years of the writer's operations. From the series of 770 roentgenograms of New York private school children, covering five years, it was possible to find the total forearm length on the majority of the films, the length of the radius on many additional when a curved wrist excluded use for the total measurement, and the hand length on practically every roentgenogram. The Merrill-Palmer and the Iowa Child Welfare Research Station roentgenograms gave full hand length in nearly all cases.

Before measurements from roentgenograms can be used either alone or in relation to measurements on the living, it is necessary to establish the uniformity of the X-ray technique and calculate the distortion (40). Throughout the New York series, the tube was focused from a distance of thirty-six inches, the Iowa Child Welfare Research Station at thirty-one, and the Merrill-Palmer at twenty-four inches. Each series, then, is uniform in itself and between thirty-six and thirty-one inches the distortion of the entire forearm is 2.8 and 3.1 mm. at two years of age and 7.1 and 8.0 mm. at eight years. For the hand, on the Iowa Child Welfare Research Station and New York films, the elongation of the image at thirty-one and thirty-six inches is 0.5 mm. at two years and 1.2 mm. at eight years; at twenty-four inches, it is 0.7 mm. and 1.6 mm.

The necessity for this small degree of correction is due to the fact that those parts of the object at the periphery of the cone of rays, i.e., farthest from the central ray, show the distortion of divergence. In the case of long bones, this is elongation and, theoretically, the measurement of the forearm on the roentgenogram should exceed the measurement on the living by 3 mm. at two years or a diameter 21 cm., increasing to an excess of 7 mm. at eight years or 31 cm. Actually, however, the discrepancy proved to be in the opposite direction. Comparison of a series of 139 measurements taken from the same landmarks on approximately the same date as the roentgenograms showed that, instead of being shorter than the radiographic measurements, the average diameters on the living were longer by more than a millimeter. This, of course, is not great and arises, obviously, from the thickness of the integument. But it is the question of the variability of the error inherent in the direct measurement which makes it significant. The average difference between measurements was +0.13 cm., with a standard deviation of 0.40; the range was from 1.1 cm. less than the roentgenogram to 0.9 plus. The amount of the variation was not dependent upon age, but upon technical difficulties—thickness of the skin, underdevelopment of the landmarks, bad position of the arm which, unlike the image on a roentgenogram, could not be recognized later and eliminated. Since in this comparison we included only measurements made after a year's experience, it is doubtful if more consistent results could be obtained on young children.

For all practical purposes, then, measurements of long bones from roentgenograms can be substituted for analogous measurements of the living. However, to obtain the greatest possible accuracy, all averages of Tables 10 to 12 are corrected and the radius length of each individual was corrected before correlation with stature.

The measurements, taken with a standard anthropometer (Alig and Baumgärtel) and sliding caliper (Colin) were length of total forearm from the proximal end of the radius to the end of the shadow of the middle finger, length of radius (the distal landmark being the point of the epiphysis corresponding to the styloid process of the adult), and hand length from the distal landmark of the radius. For both hand and forearm length, diameters were taken to the finger tip as shown by the soft tissue shadow rather than to the end of the terminal phalanx, to obtain the closest correspondence possible with measurements on the living.

Comparable age groups of boys and girls have nearly identical length of the upper arm, the total forearm, and the radius. There is, however, a tendency for the male hand to be longer than the female. The sex difference is smallest in the New York group where the girls' averages are often identical with the boys', though never greater. Between the sexes of the Detroit and Iowa Child Welfare Research Station children, there is always a gap ranging from 1 to 7 mm. The Iowa children, on the whole, have longer hands than the New York group; the Detroit averages tend to be intermediary.

The attempt to relate hand length to social groups made by Brezina and Lebzelter (15) resulted in the discovery of its dependency upon stature. Together with height increasing in the expected manner from the children of heavy laborers to those of more skilled workmen and to those of intellectual workers went longer hands from group to group. Among the younger boys from six until they became workmen themselves, hand breadth was also greater at the higher economic levels. The slim aristocratic adult hand, then, may be merely the result of maintaining a very common inheritance.

As the hand along with every other part of the body that we have considered grows in harmony with stature, so naturally does the radius. Since the most precise measurements were made on that segment, it was the one selected for correlation. The results are high and consistent (Table 8). Pearson's (37) correlations for radius and the stature of 100 adult corpses were not so high, for fifty males +.70, for fifty females +.67. Stature and femur, tibia, or humerus gave larger coefficients than stature and radius. The relationship in this series of children is practically the same for the radius and the leg.

Because it was an exact bone measurement from a roentgenogram, the length of the radius was also used to note bodily asymmetry. Studies of paired bones of adult legs and arms show in-

TABLE 10
Length of Forearm, Hand and Upper Arm: Mean, Standard Deviation and Range in Centimeters for the New York Private School Children

| Age, Years | Forearm and Hand | | | | Upper Arm | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Boys | | | | |
| 2 | 21 | 21.0 | 1.22 | 19.1—22.9 | 7 | 15.6 | 0.99 | 14.2—17.6 |
| 3 | 26 | 22.8 | 1.08 | 20.9—24.7 | 15 | 16.9 | 1.19 | 14.9—19.1 |
| 4 | 31 | 24.1 | 1.81 | 20.0—27.7 | 16 | 18.2 | 1.49 | 15.1—20.6 |
| 5 | 28 | 26.1 | 1.34 | 21.5—33.5 | 26 | 19.9 | 1.18 | 16.2—22.3 |
| 6 | 25 | 28.0 | 1.50 | 24.9—32.0 | 20 | 21.2 | 1.38 | 17.1—24.1 |
| 7 | 18 | 29.8 | 1.47 | 27.5—33.4 | 22 | 22.8 | 1.25 | 20.7—26.4 |
| 8 | 12 | 30.8 | 2.05 | 28.1—35.4 | 12 | 23.9 | 1.05 | 21.8—25.4 |
| | | | | Girls | | | | |
| 2 | 16 | 20.0 | 1.44 | 17.3—21.9 | 9 | 14.6 | 0.85 | 13.2—16.5 |
| 3 | 29 | 22.6 | 1.66 | 19.7—27.5 | 10 | 17.2 | 0.69 | 16.1—18.5 |
| 4 | 29 | 24.4 | 1.20 | 22.1—26.8 | 21 | 18.7 | 1.20 | 16.4—21.2 |
| 5 | 33 | 26.2 | 1.35 | 23.9—29.6 | 19 | 20.1 | 0.89 | 18.3—22.2 |
| 6 | 28 | 27.6 | 1.38 | 25.6—30.6 | 25 | 21.1 | 1.03 | 19.3—23.3 |
| 7 | 18 | 29.0 | 1.78 | 26.5—32.2 | 23 | 22.5 | 1.22 | 20.5—25.5 |
| 8 | 13 | 30.7 | 1.78 | 27.9—33.7 | 13 | 23.4 | 2.74 | 20.9—26.8 |

equality in 75 to 90 per cent of individuals (34). Of the arm bones, the longer is the right in 70 to 80 per cent of the cases; the left leg is longer in 50 to 70 per cent. This asymmetry has been reported absent in the fetus and newborn, and as appearing irregularly between nine and twenty-one years. The condition of the New York children between two and eight years, as it appears in the following tabulation is far from constant. The length of the left bone was subtracted from that of the right in each individual case. In eight out of the fourteen age and sex groups, the right radius is on the average the longer, in three it is equal, and in three it is exceeded by the left. The amount by which the right radius outdistances the left among Egyptian adults (the only means given by Martin (34)) is 3.4 mm. for men and 3.6 for women, considerably more than all the groups of children who average from 0.9 of a millimeter in favor of the right to 0.5 for the left. It may be that function is the predominant factor in the

| Age, Years | Children | Mean Boys | S. D. | Children | Mean Girls | S. D. |
|---|---|---|---|---|---|---|
| 2 | 13 | —0.2 | 1.70 | 11 | +0.4 | 1.43 |
| 3 | 19 | +0.2 | 1.35 | 16 | 0.0 | 1.06 |
| 4 | 26 | +0.3 | 1.51 | 30 | +0.3 | 1.79 |
| 5 | 29 | —0.4 | 2.17 | 34 | 0.0 | 1.66 |
| 6 | 22 | +0.5 | 3.14 | 23 | +0.9 | 1.38 |
| 7 | 12 | 0.0 | 2.20 | 14 | —0.5 | 2.38 |
| 8 | 9 | +0.3 | 3.26 | 7 | +0.7 | 1.83 |

TABLE 11

Radius Length: Mean, Standard Deviation and Range in Centimeters of New York Private School Children

| Age, Years | Children | Mean | S. D. | Range |
|---|---|---|---|---|
| | | Boys | | |
| 2 | 19 | 10.6 | 0.68 | 9.3—11.7 |
| 3 | 25 | 11.7 | 0.72 | 10.1—13.1 |
| 4 | 31 | 12.7 | 1.06 | 10.4—14.7 |
| 5 | 29 | 14.0 | 0.90 | 11.2—16.2 |
| 6 | 22 | 15.0 | 0.87 | 12.5—16.5 |
| 7 | 18 | 16.0 | 0.94 | 14.7—18.4 |
| 8 | 11 | 16.7 | 1.26 | 14.7—19.7 |
| | | Girls | | |
| 2 | 14 | 10.4 | 0.64 | 9.4—11.3 |
| 3 | 25 | 11.6 | 0.88 | 10.0—13.5 |
| 4 | 33 | 12.8 | 0.80 | 11.4—14.6 |
| 5 | 34 | 14.0 | 0.82 | 12.7—16.1 |
| 6 | 27 | 14.8 | 0.89 | 13.2—16.4 |
| 7 | 17 | 15.7 | 0.97 | 14.2—17.9 |
| 8 | 14 | 16.7 | 1.15 | 15.0—18.8 |

TABLE 12

Hand Length: Mean, Standard Deviation and Range in Centimeters for the New York Private School, Merrill-Palmer and Iowa Child Welfare Research Station Children

| Age, Years | New York Private Schools | | | | Merrill-Palmer School | | | | Iowa Child Welfare Research Station | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | | Boys | | | | | | | |
| 1 | | | | | | | | | 27 | 9.6 | 0.60 | 8.4—10.8 |
| 2 | 19 | 10.7 | 0.61 | 9.6—11.8 | 14 | 10.9 | 0.65 | 9.8—12.1 | 21 | 10.7 | 0.78 | 10.0—11.3 |
| 3 | 31 | 11.5 | 0.50 | 10.6—12.6 | 37 | 11.6 | 0.63 | 10.4—13.0 | 28 | 11.8 | 0.57 | 10.7—13.1 |
| 4 | 35 | 12.0 | 0.74 | 10.2—13.2 | 47 | 12.4 | 0.69 | 10.9—14.3 | 33 | 12.4 | 0.51 | 10.8—13.1 |
| 5 | 45 | 12.8 | 0.70 | 10.7—14.4 | 33 | 13.0 | | 12.3—14.0 | 36 | 13.0 | 0.68 | 11.6—14.2 |
| 6 | 30 | 13.2 | 0.65 | 11.8—14.5 | | | | | 30 | 13.7 | 0.65 | 11.9—15.0 |
| 7 | 19 | 14.1 | 0.76 | 11.6—15.6 | | | | | 37 | 14.4 | 0.69 | 13.1—15.8 |
| 8 | 13 | 14.5 | 0.63 | 13.9—15.8 | | | | | 49 | 15.0 | 0.76 | 13.3—17.2 |
| | | | | | Girls | | | | | | | |
| 1 | | | | | | | | | 28 | 8.9 | 0.56 | 7.8—10.1 |
| 2 | 16 | 10.2 | 0.60 | 9.0—11.0 | 8 | 10.5 | 0.25 | 10.2—10.9 | 18 | 10.6 | 0.49 | 9.7—11.3 |
| 3 | 29 | 11.3 | 0.54 | 10.4—12.3 | 46 | 11.3 | 0.55 | 10.4—12.8 | 31 | 11.6 | 0.60 | 10.2—12.9 |
| 4 | 35 | 11.9 | 0.58 | 10.6—13.0 | 53 | 12.1 | 0.64 | 10.6—13.3 | 40 | 12.1 | 0.44 | 11.2—13.1 |
| 5 | 44 | 12.6 | 0.54 | 11.6—14.3 | 33 | 12.7 | 0.62 | 11.7—13.7 | 47 | 12.8 | 0.60 | 11.3—14.1 |
| 6 | 32 | 13.2 | 0.44 | 12.5—14.3 | | | | | 38 | 13.4 | 0.68 | 11.9—14.7 |
| 7 | 18 | 13.9 | 0.66 | 12.7—15.1 | | | | | 34 | 14.2 | 0.81 | 12.4—16.1 |
| 8 | 14 | 14.6 | 0.69 | 13.6—15.7 | | | | | 32 | 14.5 | 0.81 | 12.9—15.9 |

asymmetrical development of the extremities, resulting in longer bones for the right arm than for the left, but the characteristic most evident during the earlier growth period is the extremely small average difference in the relationship of paired bones as represented by the radii.

In the three principal segments of the upper extremity, upper arm, radius, and hand, growth proceeds with considerable uniformity between the ages of two and eight. The upper arm, as measured on the New York children, increases annually from 1.27 to 1.74 cm. among the boys' groups and, omitting the figure for two to three years, from 0.92 to 1.53 cm. among the girls' (Table 10). The radius gains from 0.67 to 1.31 and 0.73 to 1.20, and the hand length increments range from 0.39 to 1.13 with 80 per cent of the groups less than 0.75 (Tables 10, 11, and 12). The humerus and the radius increase at about the same ratio between two and eight years: New York children, upper arm, boys 42 per cent, girls 46 per cent; radius, boys 44 per cent, girls 47 per cent. The slightly higher rate for the middle segment might be interpreted as persistence of the "law of developmental direction," but the rate of growth of the hand is a contradiction. The ratio from two to

TABLE 13

Hand-Radius Indices: Mean, Standard Deviation and Range for the New York Private School Children

| Age, Years | Children | Mean | S. D. | Range |
|---|---|---|---|---|
| | | Boys | | |
| 1 | 12 | 112.9 | 6.94 | 125—100 |
| 2 | 17 | 99.6 | 5.04 | 112—89 |
| 3 | 22 | 95.7 | 4.01 | 103—85 |
| 4 | 29 | 92.1 | 4.29 | 98—80 |
| 5 | 26 | 90.0 | 3.65 | 99—81 |
| 6 | 23 | 86.8 | 4.57 | 96—77 |
| 7 | 18 | 85.8 | 3.17 | 93—80 |
| 8 | 11 | 83.8 | 3.60 | 90—78 |
| | | Girls | | |
| 1 | 6 | 106.8 | | 118—103 |
| 2 | 9 | 97.8 | 3.65 | 105—92 |
| 3 | 24 | 96.2 | 3.88 | 104—88 |
| 4 | 28 | 91.9 | 3.95 | 98—85 |
| 5 | 33 | 87.6 | 3.44 | 96—82 |
| 6 | 26 | 87.1 | 3.50 | 93—81 |
| 7 | 17 | 86.4 | 3.62 | 92—80 |
| 8 | 13 | 84.7 | 2.78 | 89—81 |

eight is for boys from New York 30 per cent, Iowa 33 per cent; girls, New York 35 per cent, Iowa 31 per cent.

Further evidence of the different behavior of the proximal and distal segments is furnished by their relationship to one another (Tables 13 and 14). There is little change with age in the proportion of radius to humerus. The index for the New York boys is 71 at two years and 72 at seven; the girls' is 70 at two and 74 at eight years. Various racial means for adult groups given by Schultz (47) range from 76.9 to 75.3. Among the great anthropoids, the forearm is somewhat longer in relation to the upper arm than it is in man, the averages being: sixty-six orang-utans 100.7, twenty-nine chimpanzees 92.6, and fifty-one gorillas 80.7. The indices of all lower primates average from 94.9 to 115.7. That during embryonic and fetal life, the humero-radial index proceeds from a proportion similar to the gorilla's and arrives within the adult range soon after birth is shown by the following tabulation (Martin (34), page 396):

| Age | Index |
|---|---|
| 2½ Months (Embryonic) | 88.8 |
| 3 to 4 Months (Fetal) | 84.1 |
| 4 to 5 Months (Fetal) | 80.4 |
| 5 to 7 Months (Fetal) | 77.7 |
| 8 to 9 Months (Fetal) | 77.3 |

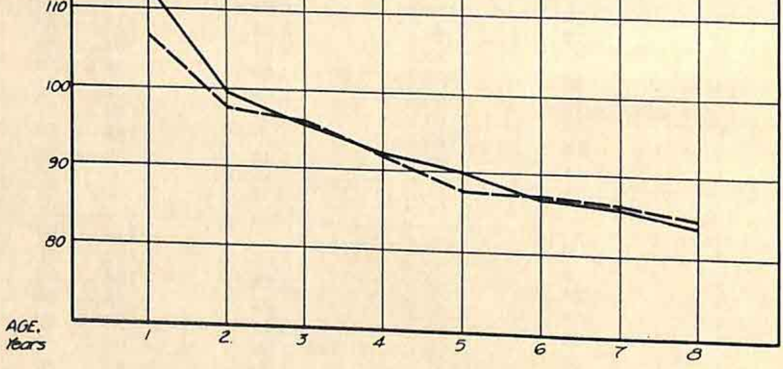

Figure 10. Hand—Radius Index for the New York Private School Children. Boys (———), Girls (- - - -)

| | |
|---|---|
| 1 to 10 Days | 76.2 |
| 11 to 20 Days | 74.8 |
| 21 to 30 Days | 74.5 |
| 2 Months | 73.0 |
| 6 Months to 2 Years | 72.5 |
| 5 Years to 13½ Years | 72.3 |

In contrast to the stable postnatal relationship of humerus to radius, the proportion of hand length to radius undergoes a steady reduction of 20 or 30 per cent between the first and the ninth year of life (Table 13). The hand has not only completed more of its ultimate growth than has the forearm; it is actually longer than the radius before two years of age and practically equal to it until four. Figure 10 gives the abrupt change between one and two years, followed by the gradual increase of the length of the radius in excess of the hand. Scammon and Calkins (45) found a constant increase in the length of the hand with respect to the forearm during the fetal period, with indices of 71.4 at three fetal months, 87.7 at six, and 89.7 at birth. From our figures, it is evident that the same relative growth rate continues for at least twelve months longer before a change in the adult direction takes place.

The relationship of the arms to the rest of the body is expressed by various indices, the span-stature index, the arm-leg index, and the trunk-arm index.

Span was measured in a simple and not entirely scientific manner. The child lay on his back on the floor with arms extended, palms flat, following a crack that ran conveniently at shoulder height. Chalk marks were made at the tips of the middle fingers, the child was hoisted up, and the distance between marks measured by a steel tape. The greatest error rose from the elasticity of the child, a quality of mind as well as of matter. There are children who rigorously limit their scope and children who can be stretched indefinitely. Under these circumstances, delicate statistical treatment of the results did not seem justified and only the age group averages for indices unaccompanied by standard deviations, are presented below:

| Age, Years | Boys | | Girls | |
|---|---|---|---|---|
| | Children | Mean | Children | Mean |
| 2 | 15 | 97.6 | 13 | 97.7 |
| 3 | 27 | 98.2 | 17 | 99.2 |
| 4 | 27 | 98.4 | 34 | 98.7 |
| 5 | 33 | 101.6 | 36 | 98.6 |
| 6 | 26 | 98.9 | 29 | 99.0 |
| 7 | 22 | 99.8 | 23 | 99.8 |
| 8 | 14 | 100.2 | 14 | 100.2 |

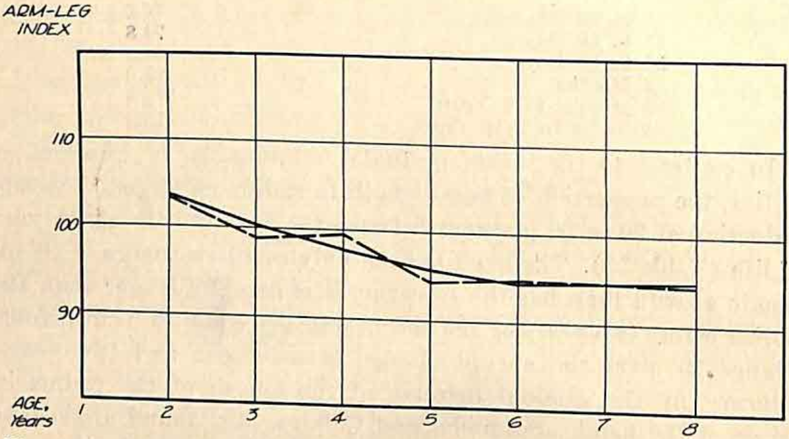

Figure 11. Arm—Leg Index for the New York Private School Children. Boys (———), Girls (- - - -)

No age or sex differences are evident. Adult females of all races and nations listed by Martin (34) have arms relatively shorter than the males but in the majority of both men and women the average indices are over 100. The means for Hrdlicka's (31) Old Americans, however, are 102.6 for men and 99.6 for women. Between the ages of two and eight, the span-stature index describes individual type rather than age. Over a period of five years, a child, whatever the age at first measurement, maintained his relative position remarkably in view of the unreliability of the records. In most cases, the yearly deviations were in tenths of 1 per cent. A child whose span was 92.8 per cent of his stature at two had an index of 92.5 at six years and another with equal span and stature at four changed only to the extent of 99.8 at eight. A more accurate technique following the same individual from early childhood to full maturity would establish to what extent a span longer or shorter than stature is a constitutional character.

Definite age changes take place in the proportion of arms to legs and to the trunk. In each case, the average indices are moving away from the type characteristic of the great apes and closely approach the adult human condition. The length of the upper extremities of all apes is much greater than that of the lower. After the fourth fetal month, Scammon found that the human arms were always longer than the legs. The index used to describe the relative proportions of the extremities, $\frac{\text{arm length x 100}}{\text{leg length}}$

TABLE 14

Humero-Radial, Trunk-Total Arm, and Arm-Leg Indices: Mean, Standard Deviation and Range for the New York Private School Children

| Age, Years | Humero-Radial Index |  |  |  | Trunk-Total Arm Index |  |  |  | Arm-Leg Index |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
|  |  |  |  |  |  | Boys |  |  |  |  |  |  |
| 2 | 7 | 70.9 | 4.08 | 64.7—77.7 | 6 | 127.9 | 2.92 | 123.5—133.0 | 7 | 103.7 | 2.31 | 109 — 101 |
| 3 | 14 | 71.3 | 2.18 | 68.3—77.8 | 15 | 129.2 | 4.97 | 117.0—137.0 | 15 | 100.3 | 2.95 | 107 — 96 |
| 4 | 16 | 72.2 | 2.74 | 67.4—78.5 | 13 | 134.0 | 8.22 | 114.8—148.7 | 16 | 97.9 | 2.54 | 102 — 94 |
| 5 | 24 | 72.4 | 3.56 | 65.9—80.0 | 23 | 134.6 | 6.44 | 119.7—147.4 | 26 | 95.9 | 2.55 | 100 — 90 |
| 6 | 20 | 72.0 | 3.66 | 66.2—78.3 | 20 | 137.8 | 8.26 | 120.4—155.6 | 20 | 94.4 | 2.59 | 100 — 89 |
| 7 | 22 | 73.5 | 2.67 | 68.2—78.4 | 20 | 141.0 | 6.29 | 130.2—153.0 | 22 | 94.6 | 2.13 | 99 — 93 |
| 8 | 12 | 72.4 | 2.44 | 68.0—77.0 | 13 | 145.4 | 4.92 | 137.4—153.0 | 12 | 94.8 | 1.98 | 99 — 92 |
|  |  |  |  |  |  | Girls |  |  |  |  |  |  |
| 2 | 9 | 69.8 | 2.78 | 64.9—74.1 | 9 | 126.0 | 4.88 | 117.8—130.6 | 9 | 103.4 | 4.02 | 111 — 97 |
| 3 | 10 | 70.7 | 3.40 | 66.5—76.9 | 10 | 131.2 | 3.35 | 125.8—137.3 | 11 | 99.0 | 2.00 | 102 — 95 |
| 4 | 21 | 71.1 | 3.47 | 64.2—78.5 | 19 | 134.6 | 3.51 | 128.1—142.6 | 20 | 99.6 | 3.26 | 102 — 88 |
| 5 | 19 | 71.6 | 1.96 | 67.3—75.4 | 19 | 135.5 | 4.83 | 127.6—145.3 | 20 | 94.5 | 2.82 | 101 — 88 |
| 6 | 24 | 72.3 | 2.50 | 67.3—76.4 | 24 | 136.7 | 5.60 | 122.2—144.8 | 25 | 94.9 | 3.32 | 101 — 89 |
| 7 | 23 | 73.0 | 3.01 | 67.0—79.2 | 21 | 139.5 | 5.43 | 125.0—148.1 | 22 | 94.6 | 2.52 | 99 — 90 |
| 8 | 13 | 73.8 | 2.36 | 69.0—77.0 | 13 | 139.2 | 6.58 | 123.2—148.7 | 9 | 94.4 | 2.51 | 99 — 91 |

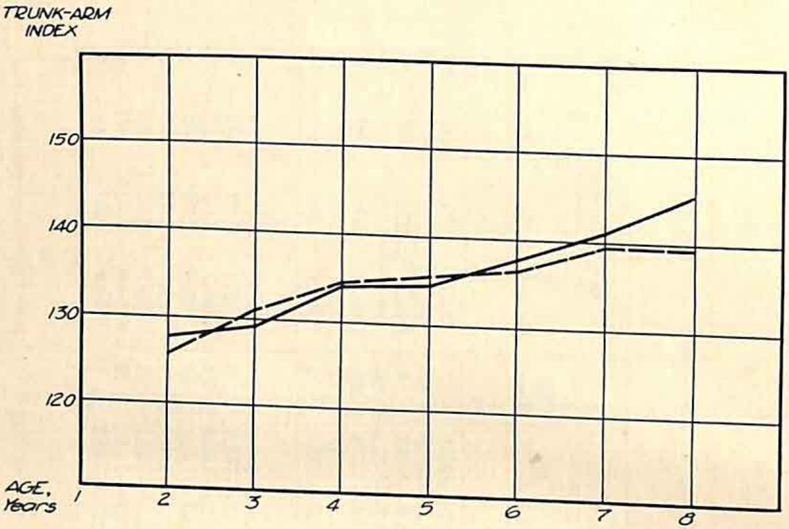

Figure 12. Trunk—Arm Index for the New York Private School Children. Boys (———), Girls (- - - -)

differs greatly from investigator to investigator because of the variety of methods for obtaining the component diameters. Therefore, the exact figures of no single study are comparable to those of another. By all methods, however, similar trends emerge; in early childhood the leg is relatively shorter than in the mature individual. Figure 11 shows the decline of the index with age. In spite of the evidence of the averages on Table 14, the leg is not actually shorter than the arm. The measure of the lower

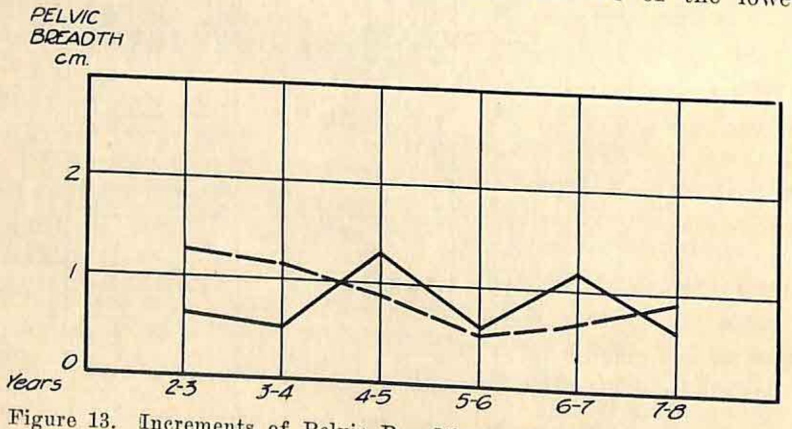

Figure 13. Increments of Pelvic Breadth for the New York Private School Children. Boys (———), Girls (- - - -)

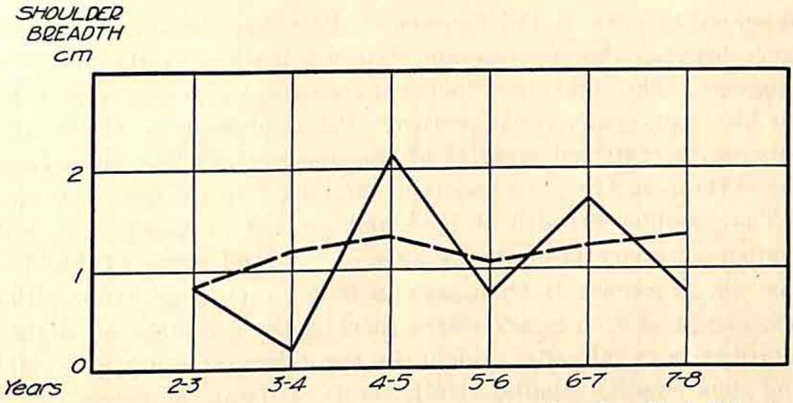

Figure 14. Increments of Shoulder Breadth for the New York Private School Children. Boys (———), Girls (- - - -)

extremity obtained by subtracting stem length from stature is, as has been already mentioned (page 43), from 10 to 15 per cent shorter than total leg length.

A lower and therefore more mature arm-leg index is shown by the girls in four of the seven age groups (Table 14). That this indicates a real sex difference could not be deduced from the New York material alone but it is corroborated by a later study of the present writer where, in large groups of children between the ages of two and eighteen years, the girls at all ages and all statures had arms shorter in relation to leg than had the boys.[4]

While the arm is growing shorter in proportion to the leg, it is increasing in relation to trunk length. Table 14 and Figure 12 record the upward trend from two to eight years. The Cercopithecidae (Old World apes) have an index range of 105-119, and adult male Germans average 153 (35). Between these limits and with a 10 per cent margin at each end of the age scale runs the course of development of the New York boys from 128 at two years to 145 at eight. From six to eight, the boys seem more mature than the girls, but an overweighting of a hereditary type in so small a sample may be responsible for the difference.

### SHOULDERS AND PELVIS

The breadth of the shoulders and the breadth of the pelvis were measured according to the standard technique used for adults. Both measurements were taken with the large sliding calipers.

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[4] Wallis, Ruth Sawtell: The relative growth of the extremities from two to eighteen years of age. Accepted for publication by the Amer. J. Physical Anthropol., December, 1931.

Shoulder breadth is the biacromial diameter, the maximum distance between the superior and external borders of the acromion processes. The child stood facing the assistant who was responsible for his erect, symmetrical posture. Pelvic breadth is the distance between the external margins of the iliac crests. The child faced the anthropometrist, the assistant checking posture from the rear.

The shoulder breadth of boys and girls is of nearly the same average diameter between the ages of two and eight (Table 15). The sex difference is from zero to 5 mm. and may favor either sex, except at four years where there is the sampling of slightly retarded boys, already evident in the tables of stature, weight, and stem length. Similar relationships exist for the pelvis (Table 15). No foreshadowing of the adult differences, the broader shoulders of the male, the broader pelvis of the female, appears during childhood. In shoulder breadth, Munich school boys from six to thirteen and one-half years do not exceed the girls until the age of twelve. The average pelvic breadth is slightly broader for boys from six to twelve years and during the next eighteen months the girls only equal the boys (Martin (34), pages 349-352).

In the discussion of the tendency of increments of stature and weight to rise and fall in alternating years, it was mentioned that

TABLE 15

Shoulder and Pelvic Breadth: Mean, Standard Deviation and Range in Centimeters for the New York Private School Children

| Age, Years | Shoulder Breadth | | | | Pelvic Breadth | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Boys | | | | |
| 2 | 5 | 21.6 | 0.87 | 20.3—22.8 | 5 | 15.4 | 1.39 | 13.7—17.0 |
| 3 | 22 | 22.4 | 1.06 | 20.4—23.8 | 19 | 16.0 | 0.80 | 14.4—17.3 |
| 4 | 21 | 22.6 | 1.90 | 19.4—26.7 | 21 | 16.5 | 0.90 | 15.3—19.5 |
| 5 | 21 | 24.8 | 1.44 | 20.6—26.9 | 23 | 17.8 | 0.79 | 15.7—19.7 |
| 6 | 19 | 25.5 | 1.47 | 21.4—28.1 | 20 | 18.4 | 0.73 | 16.8—19.4 |
| 7 | 22 | 27.2 | 1.44 | 25.4—31.5 | 22 | 19.6 | 0.83 | 18.3—21.4 |
| 8 | 14 | 28.0 | 1.60 | 25.8—32.4 | 14 | 20.2 | 1.13 | 17.6—22.5 |
| | | | | Girls | | | | |
| 2 | 9 | 21.5 | 0.53 | 20.3—22.2 | 9 | 14.8 | 0.37 | 14.3—15.4 |
| 3 | 22 | 22.3 | 0.98 | 20.1—25.0 | 21 | 16.1 | 0.68 | 14.9—17.1 |
| 4 | 23 | 23.5 | 1.16 | 21.4—26.3 | 22 | 17.2 | 0.81 | 16.0—19.3 |
| 5 | 19 | 24.8 | 1.16 | 21.9—26.7 | 20 | 18.1 | 0.88 | 16.4—19.7 |
| 6 | 25 | 25.9 | 1.38 | 22.8—29.0 | 25 | 18.6 | 0.91 | 17.1—21.0 |
| 7 | 22 | 27.1 | 1.34 | 24.5—30.3 | 23 | 19.3 | 0.99 | 18.0—21.5 |
| 8 | 13 | 28.5 | 1.42 | 26.4—30.4 | 12 | 20.2 | 1.15 | 18.4—22.2 |

TABLE 16

Shoulder-Trunk, Pelvis-Trunk and Shoulder-Pelvis Indices: Mean, Standard Deviation and Range for the New York Private School Children

| Age, Years | Shoulder-Trunk Index | | | | Pelvis-Trunk Index | | | | Shoulder-Pelvis Index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| Boys | | | | | | | | | | | | |
| 2 | 5 | 75.0 | 2.4 | 78 — 72 | 5 | 53.2 | 1.8 | 51 — 55 | 5 | 71.1 | 4.1 | 76 — 85 |
| 3 | 13 | 74.6 | 2.7 | 79 — 70 | 11 | 52.1 | 2.3 | 48 — 56 | 10 | 71.0 | 2.6 | 75 — 67 |
| 4 | 15 | 73.1 | 1.3 | 80 — 65 | 15 | 52.0 | 2.6 | 48 — 58 | 13 | 71.2 | 2.9 | 75 — 66 |
| 5 | 20 | 72.0 | 2.8 | 76 — 65 | 23 | 51.9 | 2.0 | 48 — 55 | 19 | 71.6 | 2.9 | 76 — 66 |
| 6 | 18 | 72.4 | 1.1 | 78 — 63 | 20 | 52.1 | 2.1 | 47 — 56 | 17 | 71.8 | 2.8 | 77 — 67 |
| 7 | 21 | 72.9 | 3.0 | 80 — 68 | 21 | 52.1 | 1.6 | 48 — 55 | 22 | 72.0 | 2.9 | 78 — 67 |
| 8 | 14 | 72.5 | 1.2 | 79 — 66 | 14 | 52.3 | 2.3 | 48 — 55 | 13 | 72.9 | 2.9 | 77 — 69 |
| Girls | | | | | | | | | | | | |
| 2 | 9 | 78.3 | 3.2 | 85 — 74 | 9 | 53.7 | 2.5 | 51 — 59 | 9 | 69.0 | 1.3 | 71 — 67 |
| 3 | 11 | 74.0 | 2.8 | 81 — 72 | 10 | 52.7 | 1.6 | 51 — 55 | 10 | 71.0 | 1.6 | 74 — 68 |
| 4 | 21 | 73.4 | 2.9 | 78 — 68 | 19 | 53.3 | 1.8 | 49 — 57 | 19 | 73.6 | 3.1 | 78 — 66 |
| 5 | 18 | 72.8 | 3.5 | 80 — 65 | 19 | 52.9 | 2.4 | 48 — 59 | 20 | 72.6 | 3.4 | 80 — 66 |
| 6 | 22 | 72.6 | 3.2 | 78 — 64 | 25 | 52.3 | 2.0 | 49 — 57 | 21 | 72.2 | 2.6 | 78 — 67 |
| 7 | 21 | 72.8 | 2.7 | 78 — 64 | 21 | 52.0 | 2.2 | 48 — 58 | 22 | 71.0 | 3.6 | 75 — 61 |
| 8 | 13 | 72.8 | 3.1 | 76 — 67 | 13 | 51.3 | 2.3 | 47 — 56 | 13 | 70.6 | 3.8 | 78 — 62 |

the same process was illustrated by the growth of the shoulders and the pelvis (Figures 13 and 14). The similarity of the four curves for the boys is striking, the maxima rising between four and five and between six and seven. For the transverse measures, the girls' curve is again much smoother than the boys', dipping, however, between five and six years, where the boys make their smallest gain. The rate of increase from two to eight years is uniform for those two transverse dimensions of the trunk. The boys' gain is 28 per cent for the pelvis and 26 per cent for the shoulder; the girls' 31 per cent and 30 per cent, an amount practically identical with the growth of the vertical length of the trunk.

Proportional changes in the trunk are not marked during the growth period here considered. The shoulders in relation to trunk length grow narrower (Table 16 and Figure 15), but this is not straight progress towards maturity. For this highly temperamental index turns on itself several times between the third fetal month and adult life. At three, six, and ten fetal months, the averages are 74.4, 78.9, 71.5 (Scammon and Calkins (45), pages 192-193, at two years, the mean index for boys is 75 and at eight years 72.5, while for 100 adult German males (Mollison (35)) it is 75.3, with a range of 68-88. With the exception of one gorilla child whose index was 70, all other anthropoids studied by Mollison have shoulder breadths equal to only a little more than half the trunk length, and lower apes and monkeys are so narrow-shouldered that the index is only 25 to 30 per cent.

The relation between trunk length and biacromial breadth is a highly variable personal matter with no direct age trend, but at

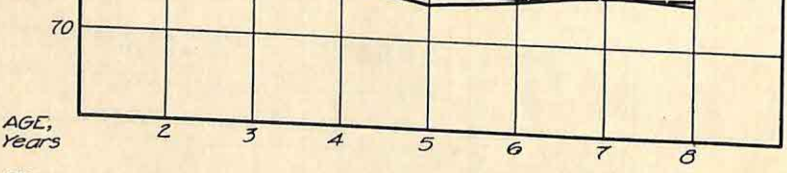

Figure 15. Shoulder—Trunk Index for the New York Private School Children. Boys (———), Girls (- - - -)

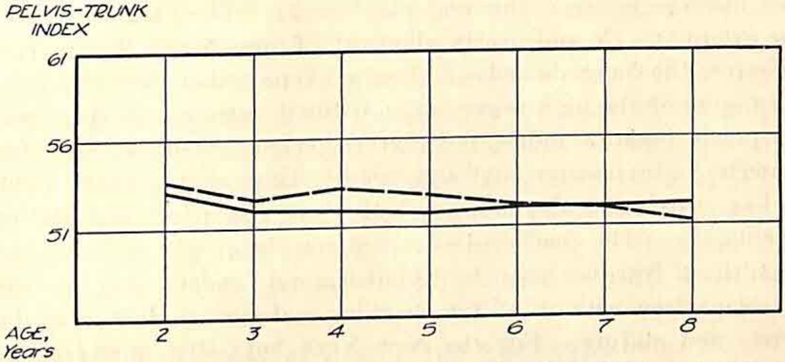

Figure 16. Pelvis—Trunk Index for the New York Private School Children. Boys (———), Girls (- - - -)

the earliest fetal stage already quite unlike the anthropoid condition. Within our age range, the trunk-bicristal index proceeds in the same manner as the trunk-biacromial index (Table 16 and Figure 16), but there is not so sharp a line between the proportions of adult males, babies, and the higher apes. Following are the averages for apes and human males; five orang-utans 52.8, eight chimpanzees 52.2, twenty gibbons 48.4, human males two years 53.2, eight years 52.3, adult 56.2.

The relations which these two transverse diameters bear to one another can be expressed by the shoulder-pelvis index and by the coefficient of correlation. Although according to Scammon and Calkins (45) the fetal pelvis grows steadily wider in relation to shoulder breadth, being 56.6 per cent of it at three fetal months, 68.5 at six months, and 70.0 at birth, there is no continuation of

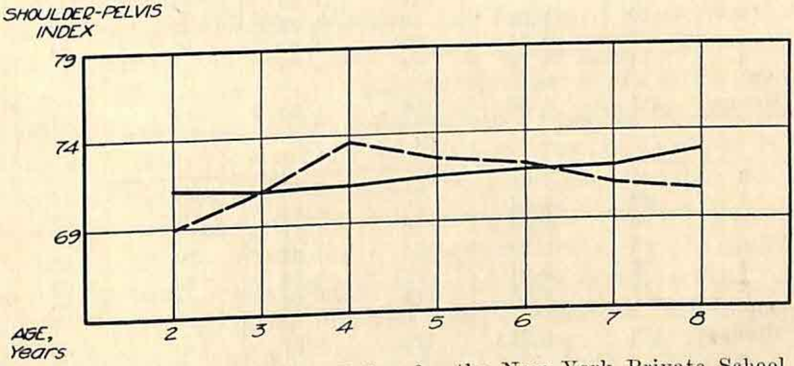

Figure 17. Shoulder—Pelvis Index for the New York Private School Children. Boys (———), Girls (- - - -)

this increase between two and eight years. The range in every age group is wide and nearly identical (Table 16 and Figure 17); therefore the index describes individual type rather than maturity.

In spite of the high degree of individual variation in the shoulder-pelvic breadth index, the correlation coefficients for the two diameters are positive and significant (Table 17). There exists a close correlation also between both these characters and stature (Table 17). The coefficient obtained for the pelvic and shoulder breadths of Swedish males by Lundborg and Linders (33) is +.38, in comparison with +.47 for shoulder and stature and +.52 for pelvis and stature. For the New York boys, the shoulder and pelvis relationship is also the lowest of the three coefficients, all of which are higher than for the Swedish adults, +.65, +.85, and +.71. The girls, however, show a uniform degree of association +.61, +.61, and +.62. The relationships of these two transverse diameters of the trunk with stature are at least as close as that of trunk length, bearing out once more the principle that from the

TABLE 17

Correlations Shoulder and Pelvis, Shoulder Breadth and Stature, and Pelvic Breadth and Stature

| Age, Years | Shoulder and Pelvis | | Shoulder and Stature | | Pelvis and Stature | |
|---|---|---|---|---|---|---|
| | Children | Correlation | Children | Correlation | Children | Correlation |
| | | | Boys | | | |
| 3 | 18 | +.39 | 21 | +.71 | 19 | +.55 |
| 4 | 20 | +.75 | 21 | +.86 | 21 | +.76 |
| 5 | 18 | +.74 | 21 | +.90 | 24 | +.66 |
| 6 | 19 | +.69 | 19 | +.93 | 18 | +.77 |
| 7 | 22 | +.64 | 22 | +.87 | 22 | +.74 |
| 8 | 14 | +.70 | 14 | +.79 | 14 | +.84 |
| All Groups | 111 | +.65 | 118 | +.85 | 118 | +.71 |
| | | | Girls | | | |
| 3 | 21 | +.61 | 21 | +.53 | 20 | +.46 |
| 4 | 22 | +.58 | 20 | +.61 | 22 | +.64 |
| 5 | 20 | +.56 | 19 | +.51 | 20 | +.55 |
| 6 | 25 | +.80 | 25 | +.66 | 24 | +.67 |
| 7 | 22 | +.54 | 22 | +.74 | 23 | +.69 |
| 8 | 13 | +.48 | 13 | +.56 | 13 | +.70 |
| All Groups | 123 | +.61 | 120 | +.61 | 122 | +.62 |

earliest fetal stage all dimensions of the body bear a constant relationship to the measure of its total size.

### HEAD AND FACE

The six measurements of the head and face of the New York children immediately present characteristics which set them apart from the traits hitherto described. Here, there is a clear and consistent sex difference in every diameter. The interrelationships change regularly with age and the relative size of the indices for the two sexes shifts at least once between the ages of two and eight.

For the maximum head length from glabella to occiput and the greatest transverse breadth, the spreading calipers were used. The same instrument recorded the facial breadth between the most widely separated points of the zygomatic arches and the breadth of the lower jaw from gonion to gonion, the points of the angles formed by the ascending branches with the body of the mandible. Two facial heights were measured, one from nasion, the depression where the frontal and nasal bones meet, to gnathion, the midpoint of the bony chin, and a second from nasion to prosthion, between the two upper central incisors. The height from nasal bridge to chin was taken with the spreading calipers, the upper facial height with the small sliding calipers. The second measure is better adapted to comparison between children of different age groups because it is not affected by the loss or acquisition of teeth.

In head length and breadth, face width and height, and the breadth of the lower jaw, boys at every age have larger averages than do girls (Tables 18 and 19). Men of all races have larger head and face measurements than women. This supremacy is held also in stature, shoulder breadth, and length of the extremities, but during growth as we have seen this adult sex difference in comparable age groups is not apparent because of the girls' shorter period of growth and more rapid rate of development. Professor Boas (8) stated twenty years ago, that in those parts of the body which complete their growth at a very early time, secondary sexual characters are established in childhood, basing his belief firmly on records of the head and face. A recent study by the present writer extended the principle to the breadth of the radius (42) and this study indicates that throughout childhood the tibia and the humerus of boys are also broader than the bones of girls of equal age.

The percentage of increment for the two diameters of the head shows how great an amount of the ultimate growth has been attained before the age of two years. The male and female gain in head length from two to eight years is 9 per cent, for head breadth 5 per cent and 7 per cent, whereas the ratio for trunk length is 28 per cent and 44 per cent, and 49 per cent for leg length. Thus the "law of developmental direction" pursues its course from top to toe. Long before two years, the final sex difference is established. It has begun at birth and continues, as in the New York private school children, throughout all ages of Europeans, Chinese, Negroes, and mixed groups (28), (57). However, the actual difference between boys and girls is less than between men and women. The sex differences for length and breadth of head of children are contrasted with those of adults in the following tabulation:

| Children | Age, Years | Children's Difference | Adults' Difference |
|---|---|---|---|
| | Length | | |
| New York Private Schools | 2 — 8 | 4.1 | 11.4 |
| Worcester Public Schools | 5 — 8 | 4.4 | |
| American Negroes | 2 — 8 | 3.5 | 9.5 |
| Bohemians, American-born | 4 — 8 | 6.9 | 9.3 |
| Dutch | 13 | 3.4 | 6.1 |
| | Breadth | | |
| New York Private Schools | 2 — 8 | 4.4 | 6.5 |
| Worcester Public Schools | 5 — 8 | 3.1 | |
| American Negroes | 2 — 8 | 3.1 | 6.0 |
| Bohemians, American-born | 4 — 8 | 4.8 | 5.8 |
| Dutch | 13 | 5.6 | 8.2 |

The American-born Bohemians are from Boas' (7) study of immigrants, the Negroes after Herskovits (28), the Dutch from Bolk's study summarized in the second volume of Martin's Lehrbüch (Martin 34, page 767) and the Worcester children calculated from Boas and Wissler's (6) *Statistics of Growth*. The adults compared with the New York and Worcester children are Hrdlicka's (31) Old Americans.

With growth, the proportions of head and face undergo various changes. The head grows longer in relation to its breadth, facial breadth increases in relation to face. Both the upper and the total height of the face grow longer in proportion to head width, jaw breadth increases in relation to face breadth (Tables 17 and 20). Although there is an orderly progression in the decrease of the index of head length and breadth and the increase of the other four indices, they are not scales for rating individual maturity. As in the case of the stem-stature index, the annual reduction or gain in any of the head and face indices due to a change of rate in one of the constituents during childhood cannot be separated from an individual's constitutional type. The respective importance of the parts played by growth and by heredity has yet to be estimated.

Head form has long been considered a sure criterion of race and numerous studies have traced and placed human origins by the cephalic index alone. The stability of the relationship of cranial length to breadth, maintained for generations in a given environment seemed immutable and the three arbitrary divisions of the index coincident with primary biologic types. When stature and pigmentation were added to the classification, it was not hard to begin to call names such as Nordic and Alpine, and racial and, therefore, social superiority ended with a cephalic index of 76.9 if you were hirsute and living and 74.9 if you were macerated and dead. Fortunately, few laymen and no scientists can calculate a cephalic index to two decimal places at a single glance.

Then came Professor Boas' (7) evidence that this most stable of physical characters was modified by a change of environment. In the slums of New York City, the remarkably round heads of the east European Hebrews became longer, and the head of southern Italians, exceedingly long and narrow in their native country, took on a shorter, fuller form. Why? Hebrews from the European ghettos showed an increase of stature and weight even in the most congested parts of New York, an environment more favorable to their general development. The Italians were somewhat shorter and lighter in the poorer American environment. Between stature and head length, there is positive correlation; therefore with an average increase or decrease in height, the form of the head would be modified by a greater or smaller glabello-occipital diameter. The proportion is not related to stature in the same way as the diameter. For example, in the series of Swedish males studied by Lundborg and Linders (33) used previously for comparison, the coefficients of correlation are +.25 for stature and head length and —0.13 for stature and cephalic index.

## TABLE 18

Head Length, Head Breadth, and Cephalic Index: Mean, Standard Deviation and Range in Millimeters for the New York Private School Children

| Age, Years | Head Length |  |  |  | Head Breadth |  |  |  | Cephalic Index |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| Boys |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | 15 | 158.1 | 4.98 | 150 — 168 | 15 | 131.4 | 5.85 | 124 — 144 | 15 | 83.2 | 4.16 | 76 — 95 |
| 2 | 14 | 167.5 | 6.90 | 152 — 179 | 16 | 137.6 | 5.11 | 129 — 144 | 16 | 83.0 | 4.94 | 75 — 94 |
| 3 | 24 | 171.0 | 6.68 | 156 — 182 | 24 | 140.3 | 5.66 | 132 — 156 | 24 | 82.3 | 5.46 | 75 — 98 |
| 4 | 20 | 172.4 | 6.70 | 158 — 182 | 20 | 141.9 | 6.64 | 131 — 156 | 20 | 82.5 | 5.55 | 76 — 96 |
| 5 | 26 | 176.4 | 5.99 | 161 — 187 | 26 | 143.0 | 7.06 | 134 — 161 | 26 | 80.8 | 4.48 | 74 — 96 |
| 6 | 20 | 177.8 | 5.28 | 168 — 187 | 20 | 142.4 | 6.78 | 134 — 153 | 20 | 80.2 | 4.64 | 74 — 94 |
| 7 | 22 | 182.9 | 5.92 | 169 — 198 | 21 | 143.8 | 5.64 | 135 — 157 | 21 | 78.7 | 3.73 | 75 — 85 |
| 8 | 16 | 183.5 | 6.50 | 171 — 199 | 16 | 144.4 | 4.50 | 137 — 154 | 16 | 78.8 | 3.81 | 72 — 85 |
| Girls |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | 8 | 155.8 | 6.10 | 144 — 164 | 8 | 127.7 | 3.80 | 121 — 133 | 8 | 82.2 | 5.18 | 75 — 92 |
| 2 | 16 | 162.6 | 4.90 | 152 — 173 | 18 | 132.0 | 2.96 | 126 — 138 | 18 | 81.5 | 2.57 | 76 — 86 |
| 3 | 26 | 168.1 | 5.73 | 157 — 180 | 27 | 135.0 | 4.50 | 125 — 143 | 26 | 80.3 | 3.84 | 73 — 87 |
| 4 | 24 | 170.4 | 6.11 | 159 — 180 | 24 | 136.8 | 4.28 | 130 — 143 | 24 | 80.3 | 3.06 | 76 — 87 |
| 5 | 20 | 174.2 | 5.27 | 163 — 183 | 20 | 138.5 | 3.68 | 132 — 145 | 20 | 79.5 | 1.88 | 76 — 83 |
| 6 | 26 | 175.5 | 5.77 | 163 — 185 | 26 | 139.7 | 4.79 | 132 — 148 | 26 | 79.7 | 3.09 | 73 — 85 |
| 7 | 23 | 177.8 | 5.08 | 169 — 186 | 23 | 141.4 | 4.74 | 133 — 149 | 23 | 79.7 | 3.52 | 73 — 87 |
| 8 | 15 | 177.9 | 5.26 | 174 — 189 | 15 | 141.7 | 5.41 | 134 — 153 | 15 | 78.8 | 3.76 | 73 — 86 |

TABLE 19

Face Breadth, Mandible Breadth, Total Face Height, and Upper Face Height: Mean, Standard Deviation and Range in Millimeters for the New York Private School Children

| Age, Years | Face Breadth | | | | Mandible Breadth | | | | Total Face Height | | | | Upper Face Height | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | | | | | Boys | | | | | | | | |
| 1 | 8 | 105.5 | 5.36 | 98—115 | | | | | | | | | | | | |
| 2 | 7 | 111.4 | 2.92 | 106—116 | 7 | 74.4 | | 69 — 76 | 9 | 75.7 | 3.20 | 72 — 83 | 4 | 47.8 | | 45 — 50 |
| 3 | 17 | 111.2 | 5.61 | 99—124 | 14 | 76.2 | 3.91 | 68 — 83 | 20 | 80.2 | 4.53 | 72 — 92 | 10 | 47.7 | 1.95 | 45 — 50 |
| 4 | 17 | 111.7 | 5.52 | 100—124 | 15 | 77.9 | 3.60 | 70 — 83 | 19 | 82.6 | 3.30 | 76 — 90 | 10 | 50.0 | 2.45 | 46 — 53 |
| 5 | 26 | 114.2 | 5.31 | 102—127 | 26 | 81.0 | 4.10 | 74 — 87 | 25 | 86.4 | 4.09 | 80 — 95 | 13 | 54.2 | 2.28 | 51 — 59 |
| 6 | 20 | 115.4 | 4.89 | 105—127 | 20 | 82.6 | 3.72 | 74 — 88 | 20 | 89.4 | 3.27 | 82 — 97 | 15 | 55.7 | 2.18 | 52 — 59 |
| 7 | 22 | 117.4 | 4.81 | 108—129 | 21 | 85.6 | 4.12 | 75 — 93 | 22 | 92.2 | 4.72 | 81 —103 | 15 | 57.2 | 2.61 | 52 — 62 |
| 8 | 16 | 118.9 | 5.13 | 109—128 | 16 | 87.6 | 4.20 | 80 — 93 | 15 | 93.9 | 5.26 | 85 —103 | 11 | 57.6 | 3.05 | 52 — 64 |
| | | | | | | | | Girls | | | | | | | | |
| 2 | 11 | 105.5 | 2.43 | 101—110 | 8 | 70.9 | | 66 — 76 | 10 | 73.1 | 3.27 | 67 — 78 | 5 | 44.6 | | 43 — 47 |
| 3 | 15 | 107.6 | 4.44 | 97—114 | 13 | 74.1 | 4.05 | 68 — 83 | 22 | 78.1 | 3.64 | 73 — 83 | 6 | 48.7 | | 45 — 52 |
| 4 | 21 | 109.7 | 4.83 | 100—119 | 21 | 77.6 | 3.90 | 69 — 85 | 23 | 81.9 | 4.29 | 75 — 91 | 18 | 48.8 | 3.17 | 43 — 55 |
| 5 | 20 | 111.2 | 4.07 | 104—118 | 20 | 79.8 | 3.95 | 72 — 85 | 19 | 84.6 | 3.94 | 78 — 93 | 14 | 51.9 | 2.22 | 47 — 55 |
| 6 | 26 | 112.9 | 4.27 | 104—119 | 26 | 79.9 | 3.67 | 74 — 89 | 25 | 86.3 | 3.78 | 78 — 94 | 12 | 53.6 | 2.33 | 50 — 57 |
| 7 | 23 | 114.9 | 3.83 | 107—121 | 22 | 83.1 | 3.95 | 77 — 92 | 22 | 89.5 | 4.85 | 83 — 99 | 17 | 55.2 | 3.33 | 51 — 63 |
| 8 | 15 | 117.4 | 4.05 | 111—124 | 15 | 85.7 | 4.07 | 80 — 95 | 15 | 92.8 | 3.55 | 87 — 98 | 14 | 56.5 | 2.67 | 53 — 61 |

It might be deduced that private school children since they are taller than offspring of the general population would be relatively longer headed than their original family lines, and that something similar would be true of the other proportions of head and face. But every group is a mixture of European origins and no European country is made up of pure types dwelling in unity. Therefore, from the cephalic index, the head breadth-face breadth and face breadth-jaw breadth indices, and the indices of facial height and breadth, we can be sure of nothing but the age trend and sex differences visible even through a maze of hereditary types and environmental influences, impossible either to estimate or to separate.

Table 18 and Figure 18 show that for both boys and girls, the cephalic index decreases with age. All babies are rounder headed than are adults, and in most racial groups, a woman's head is 1 or 2 per cent broader than is a man's. During growth, however, this small eventual difference does not run consistently along the age range. Unlike the uniform sex difference in the diameters, the indices of boys are higher than the girls' at one age, lower at another. From one to six years of age, throughout the preschool period, it is the boys who retain the more infantile form. At about six years, nine months, the index lines meet, the boys becoming equally long-headed. Averages for the Worcester children (6), calculated in the same age grouping as we have used for our own material, are consistently higher for the girls from six to eight and for the boys at five. In Wissler's (57) groups of children of north and south European origin attending school in Hawaii, the means for boys and girls coincide at six years, but

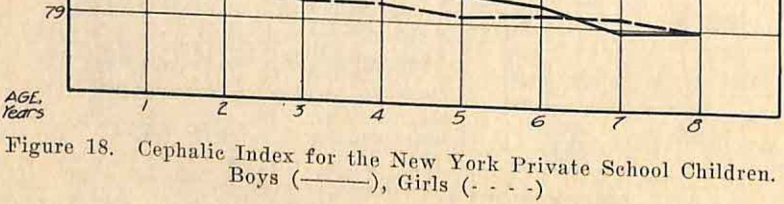

Figure 18. Cephalic Index for the New York Private School Children. Boys (———), Girls (- - - -)

the boys thereafter are rounder headed until the age of fifteen. Dr. Wissler has also found this final shift of the index to the adult sex proportion in Hawaiian, Chinese, Japanese, and Korean children of the same age. The earlier shift illustrated by the New York and Worcester children is also characteristic of American-born Neapolitan children from Boas' (7) study of immigrants where boys are the rounder headed at four and five years and the longer from six to nine. No such crossing is evident in three other American-born groups. Of the Bohemians, it is the girls who are rounder headed at four and five years, and from then until adult life, the two sexes have identical averages. Between four and nine years, the Sicilian girls' indices are always higher, and the Hebrew boys and girls shift their values back and forth almost yearly. A very different racial group, the Negroes measured by Herskovits (28), also fluctuate between the ages of two and nine. However, for relatively long-headed children of predominantly north European origin, there are clear-cut sex differences in the cephalic which are equally evident in various groups of similar composition. A recent analysis of the measurements at the Iowa Child Welfare Research Station gave the following results[5]: from two to five years of age, the boys are the rounder headed, the indices of both sexes are equal from six to nine years; between nine and twelve the girls are again longer headed and continue with this proportion until sixteen when they are equalled

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[5] Wallis, Ruth Sawtell, and Toof, Mary Esther: Age and sex differences in the cephalic index from two to eighteen years of age. Accepted for publication by the Amer. J. Physical Anthropol.

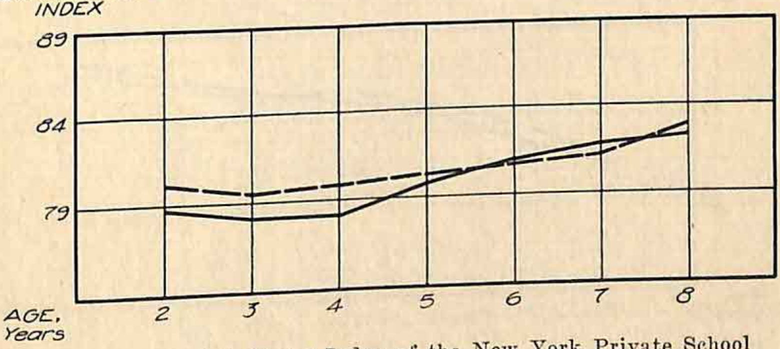

Figure 19. Cephalo-Facial Index of the New York Private School Children. Boys (———), Girls (- - - -)

and then surpassed by the boys. The curve of these age and sex differences from the Iowa records might well be a composite of the graphs drawn for Wissler's Honolulu school children of north European origin and for the New York preschool group (Figure 18). The characteristic adult status, the female skull slightly rounder than that of the male, is at last reached between sixteen and eighteen years.

The cephalo-facial index of maximum head and face breadth increases slightly year by year, the face growing relatively broader (Table 20). According to Martin (34), this index is higher in long-headed races than in the round-headed and the rise occurs among the New York children as the head grows longer. Before six years of age, the boys' index crosses the girls' but without indication that it has permanently assumed the adult position which is higher for males than for females (Figure 19). Judging from all the racial groups of Wissler's (57) Hawaiian study girls from seven to fifteen have the relatively wider faces; then the boys overtake the girls. All the racial groups at seven years have indices of about 82.0 for males and 83.0 for females which are the New York averages for the eight-year groups. Racial differences are not established, then, until growth is nearly completed. Comparison with the standard deviations for the cephalic index (Table 18), shows that the cephalo-facial index is considerably less variable for children of the same age.

The lower jaw-face breadth index (zygomatico-mandibular) varies much as does the head-face breadth index. The increase from two to eight years is greater, the jaw showing a 7 per cent gain in

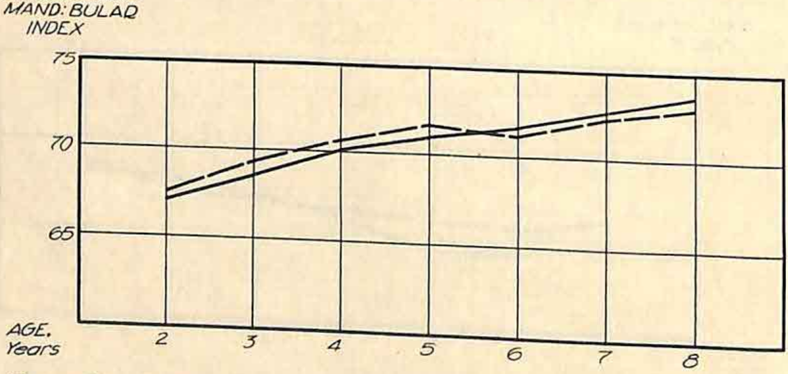

Figure 20. Zygomatico—Mandibular Index for the New York Private School Children. Boys (———), Girls (- - - -)

TABLE 20

Cephalo-Facial, Zygomatico-Mandibular, Facial, and Upper-Facial Indices: Mean, Standard Deviation and Range for the New York Private School Children

| Age, Years | Cephalo-Facial Index | | | | Zygomatico-Mandibular Index | | | | Facial Index | | | | Upper Facial Index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| Boys | | | | | | | | | | | | | | | | |
| 1 | 7 | 79.4 | 1.94 | 75 — 82 | | | | | | | | | | | | |
| 2 | 8 | 78.8 | 2.44 | 73 — 82 | 6 | 67.1 | 2.26 | 64 — 71 | 8 | 69.1 | 3.61 | 65 — 74 | | | | |
| 3 | 22 | 78.3 | 2.51 | 73 — 80 | 13 | 68.6 | 3.29 | 64 — 75 | 15 | 72.1 | 3.41 | 65 — 77 | 10 | 42.8 | 2.52 | 40 — 49 |
| 4 | 20 | 78.3 | 1.83 | 75 — 82 | 16 | 70.2 | 2.83 | 66 — 75 | 17 | 74.5 | 3.15 | 68 — 81 | 10 | 44.2 | 1.32 | 42 — 46 |
| 5 | 26 | 79.8 | 2.22 | 76 — 84 | 26 | 71.0 | 2.44 | 67 — 75 | 25 | 76.5 | 4.82 | 70 — 95 | 14 | 46.8 | 2.60 | 43 — 53 |
| 6 | 20 | 81.1 | 2.46 | 77 — 85 | 20 | 71.7 | 2.71 | 67 — 78 | 20 | 77.5 | 2.76 | 73 — 83 | 16 | 48.1 | 2.35 | 42 — 53 |
| 7 | 21 | 81.9 | 2.59 | 77 — 88 | 21 | 72.6 | 2.36 | 68 — 78 | 21 | 78.6 | 3.77 | 70 — 87 | 15 | 48.5 | 1.70 | 44 — 52 |
| 8 | 16 | 82.3 | 2.84 | 77 — 89 | 16 | 73.6 | 2.16 | 70 — 79 | 15 | 78.9 | 4.42 | 69 — 87 | 13 | 48.7 | 2.50 | 44 — 53 |
| Girls | | | | | | | | | | | | | | | | |
| 2 | 11 | 80.3 | 2.54 | 77 — 86 | 9 | 67.6 | 3.37 | 63 — 72 | 9 | 69.0 | 3.00 | 64 — 73 | | | | |
| 3 | 24 | 79.6 | 2.72 | 75 — 85 | 14 | 69.4 | 2.57 | 65 — 73 | 16 | 71.4 | 2.82 | 68 — 77 | | | | |
| 4 | 23 | 79.9 | 2.89 | 73 — 86 | 21 | 70.7 | 2.96 | 67 — 77 | 22 | 74.9 | 3.74 | 66 — 83 | 16 | 44.6 | 2.34 | 41 — 48 |
| 5 | 20 | 80.4 | 2.57 | 76 — 86 | 19 | 71.7 | 2.68 | 67 — 79 | 20 | 76.1 | 3.70 | 68 — 84 | 15 | 46.7 | 1.81 | 44 — 50 |
| 6 | 26 | 80.8 | 2.40 | 77 — 87 | 25 | 71.2 | 2.31 | 68 — 76 | 25 | 76.5 | 4.25 | 66 — 83 | 12 | 47.2 | 2.80 | 42 — 51 |
| 7 | 23 | 81.2 | 1.38 | 79 — 85 | 23 | 72.3 | 2.93 | 67 — 79 | 22 | 78.0 | 4.04 | 69 — 83 | 17 | 48.1 | 2.60 | 43 — 52 |
| 8 | 15 | 82.9 | 1.93 | 80 — 87 | 15 | 73.0 | 2.86 | 70 — 80 | 15 | 79.3 | 4.48 | 69 — 86 | 15 | 48.1 | 2.07 | 44 — 51 |

relation to the facial width. Once again, the boys begin with the lower and less mature index, but pass the girls between five and six years (Table 20 and Figure 20). From six to adult, there is practically no relative increase of jaw breadth in Wissler's (57) north and south European groups and no sex difference. Other racial groups in Hawaii differed slightly and irregularly.

The two facial indices rise rapidly with age, the boys' nearly always ahead (Table 20, Figure 21). Adult males from most of the racial groups listed by Martin ((34), pages 900-903) have longer faces than the females. The Honolulu school boys of European origin are also longer faced than the girls, and this same sex difference is characteristic of Hawaiian, Korean, Chinese and Japanese children.

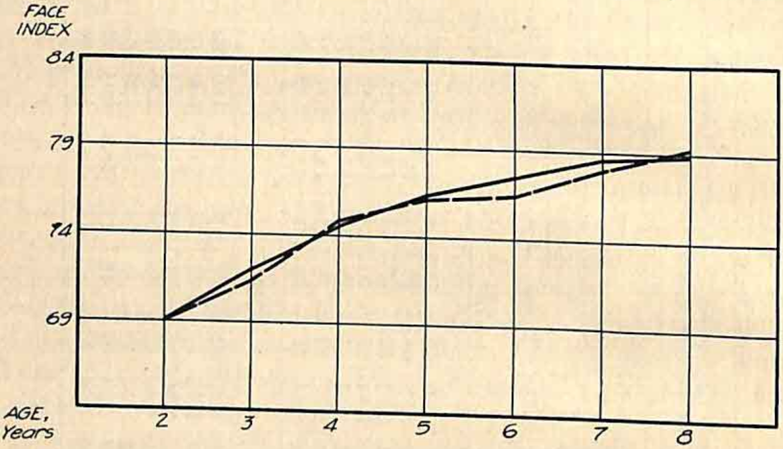

Figure 21. Face Index for the New York Private School Children. Boys (———), Girls (- - - -)

FACTORS OF GROWTH

The growth of each of the fifteen measurements of the body just discussed proceeds according to age, sex, and stature as has been stressed repeatedly. Now the effect of these three factors as they influence all the characters and proportions will be brought together.

*Age*

The influence of age, in addition to the obvious increase of size, is seen most clearly in the rate of growth as a whole, the different rate for different parts of the body, and the consequent change in the relationship of the parts. The two gross measurements, stature and weight, increase at diverse ratios between the ages of two and eight years, weight gaining at nearly twice the rate of stature. The segments of stature from head to tibia follow the law of developmental direction, the more proximal having completed successively a greater per cent of their ultimate size. The transverse measurements of the trunk proceed at approximately the same rate as the vertical dimension. The ratios of boys and girls are averaged in the following tabulation, since no indisputable sex differences were found.

| Trait | Per cent |
|---|---|
| Weight | 69.5 |
| Stature | 36.5 |
| Head Length | 9.0 |
| Head Breadth | 8.0 |
| Trunk Length | 28.0 |
| Shoulder Breadth | 28.0 |
| Pelvic Breadth | 29.0 |
| Leg | 46.5 |
| Humerus | 44.0 |
| Radius | 46.0 |
| Hand | 33.0 |

Another way of illustrating age and rates of growth is used below, where a rough attempt is made to estimate the per cent of adult growth attained at three and at eight years by relating the New York girls' averages to those of 100 Smith College students with a mean age of twenty years (50). Here the same relationships prevail as in the preceding analysis. Weight between eight and twenty still has the greatest gain to make of any of the measurements. The head, the trunk dimensions, and the legs maintain their relative positions. The three segments of the upper arm have an equal distance to go.

| Trait | Per cent 3 Years | Per cent 8 Years |
|---|---|---|
| Height | 60 | 79 |
| Weight | 26 | 48 |
| Stem Length | 65 | 81 |
| Shoulder Breadth | 63 | 80 |
| Pelvic Breadth | 64 | 81 |
| Head Length | 90 | 96 |
| Head Breadth | 92 | 98 |
| Face Breadth | 82 | 87 |
| Jaw Breadth | 74 | 85 |
| Humerus | 59 | 80 |
| Radius | 54 | 78 |
| Hand | 61 | 78 |
| Leg | 65 | 89 |

A slight check on the validity of these comparisons is furnished by the per cent of increased stature of the same individuals between childhood and the adult stage. For twenty-six boys from Newark Academy first measured at ten years, the ratio to their own adult stature is 77 per cent. The ratio of the New York girls' height at eight to the Smith girls' at twenty is 79.

Among children from two to eight years, the trend of proportional changes with increasing age, irrespective of the degree of increase or decrease, may be briefly stated as follows:

Weight increases in relation to stature.
Stem length decreases in relation to stature.
Shoulder breadth decreases in relation to trunk length.
Pelvic breadth decreases in relation to trunk length.
Pelvic breadth increases in relation to shoulder breadth.
Radius length increases in relation to humerus length.
Radius length increases in relation to hand length.
Leg length increases in relation to trunk length.
Head length increases in relation to head breadth.
Face breadth increases in relation to head breadth.
Jaw breadth increases in relation to face breadth.
Face length increases in relation to face breadth.

### *Sex*

Sex differences in size are not very remarkable during the years between two and eight. The average stature, weight and hand length of boys tends to be consistently though slightly higher, but measurements of trunk, shoulder and pelvis, and the lengths of arms and legs are almost uniformly equal for both sexes. Only in the size of head and face and the breadth of long bones does the small boy display unchallenged his adult superiority.

For nearly all characters, the New York boys are more variable throughout this growth period than are the girls, but since in the few measures collected from the Detroit and Iowa groups, standard deviations for males are equal to or slightly less than those for females, this must, until larger groups are available, be interpreted as the result of sampling.

Most of the indices of bodily characters show more or less sex difference. In general the proportions of the girls have reached a higher stage of maturity at each age before six. This is true of the stem-stature, hand-radius, trunk-arm, and arm-leg indices. Among the boys, three of the five head and facial indices, the cephalic, cephalo-facial and zygomatico-mandibular, are farther from adult proportions than they are in girls before the age of six.

### *Stature*

Throughout the age range of our study, the physical characters selected for correlation with stature show significant association. The relationship of the transverse measures of the trunk, of shoulder and pelvic breadth, is as close as the vertical dimension. The radius and the leg give higher and nearly equal coefficients. In measuring the interdependence of these parts by a further device, the regression equation, evidence appears to indicate that leg length is most closely tied to stature. These regression equations are given below:

y = Stature

| | Boys | Girls |
|---|---|---|
| Trunk | x = .25y | x = .30y |
| Leg | x = .47y | x = .35y |
| Radius | x = .16y | x = .17y |
| Shoulder | x = .25y | x = .18y |
| Pelvis | x = .12y | x = .13y |

When a boy makes an increase of one unit in stature his leg length grows 0.47 or nearly half a unit, while the gain in trunk length and shoulder breadth is 0.25 or one quarter, and in radius length and pelvic breadth 0.16 and 0.12. The figures for girls differ slightly in size but the ranking remains significantly the same, leg length bearing the closest relationship and pelvic breadth the least.

Stature as the determining factor in the size of other bodily dimensions in adults was brought forward by two studies published in 1926, that of Bach (2) made on large numbers of young men and women between eighteen and thirty-four years of age, and Lundborg and Linders' (33) frequently quoted measurements of 47,387 Swedish conscripts. Bach's grouping of stem length, shoulder breadth, pelvic breadth, arm length, and leg length according to stature showed that for every 3 cm. interval of height, the averages of all the other traits increased regularly. The coefficients of correlation for stature and several bodily dimensions obtained from the measurements of the young Swedish adults appear below, together with the weighted and averaged group coefficients of the New York private school boys. The significance of the relationship of the rest of the body to stature is inescapable whatever the age of the subject, the size of the group, or the statistical method employed. For most striking of all are the results obtained by Scammon and Calkins (45), page 263) in their fine study of the

| | New York Boys Correlation | Swedish Conscripts Correlation |
|---|---|---|
| Stature and Trunk | +.60 | +.50 |
| Stature and Leg | +.87 | +.87 |
| Stature and Radius | +.84 | |
| Stature and Shoulder | +.85 | +.47 |
| Stature and Pelvis | +.71 | +.52 |

human fetus where, by the method of analytic expressions determined from empirical formulae, they conclude:

"*First,* the growth of the external dimensions of the body in the fetal period is directly proportional to the linear growth of the body as a whole and that of other external dimensions of the body.

"*Second,* the absolute growth rate of each external dimension of the body, with respect to the absolute linear growth rate of the body as a whole, is usually established when the fetus is between 3 and 10 cm. in crown-heel length, and remains unchanged to birth."

So from fetus to adult, from 5 cm. to 200 cm., from the beginning to the end, the external dimensions of the human body proceed in harmony with its total length.

# CHAPTER III

## THE OSSIFICATION OF THE EXTREMITIES

### INTRODUCTION

Ossification, the changing of infant cartilage to adult bone, proceeds in the normal child according to his age, sex, and stature. At different times during growth, these factors shift their relative importance and always they are modified by obscure hereditary rate and environmental conditions both economic and hygienic.

Ossification, as it appears on a roentgenogram, may be studied from two points of view, the beginning and the end. The first appearance of calcium deposition may be noted and the rate of spreading ossification calculated in the stages before epiphyses begin to join diaphyses and the outlines of carpals and tarsals take on their adult form. Or starting at five and a half years with the appearance of definite outlines for hitherto amorphous centers and epiphyses, development may be followed during the next twenty years until all union of epiphyses with diaphyses is completed (27), (54). Obviously, the second method could be applied to only a small proportion of the age groups between one and eight years. But the simple quantitative measures were equally adapted to both ends of our scale, set forth clearly the age and sex differences in size, variability, and rate of growth, correlated well among themselves and with stature, and paralleled the qualitative development in the same part of the body.

On three portions of the extremities, the hand and wrist, the foot and ankle, and the head of the humerus, a detailed study was made of the appearance of points of ossification in the carpus and tarsus, and the development of epiphyses for the head of the humerus, for the radius both distal and proximal, for the ulna (distal), for the metatarsals, metacarpals and phalanges, the fibula and the calcaneum. The relationship of various epiphyses to their diaphyses was also calculated, the index thus obtained showing the proportion of the spread of ossification in the epiphyses to the growth in breadth of bone shaft.

*Data*

The sources of roentgenographic material were the same as for stature, with the addition of two large groups. All children from the New York, Merrill-Palmer and Iowa groups had films of the hand; in all the New York and a few of the Detroit records, the proximal end of the radius was present. During the last two years of the research program, roentgenograms of the foot were made for all the New York children. Of the two new sources of material, one was the white public school children of Atlanta, Georgia, studied by Dr. Clinton C. Howard (29). From Dr. Howard's tables, it was possible to calculate the average number and standard deviation of carpal bones and the percentage of cases in which the distal epiphysis of the ulna was present for each age group from five through eight. The second body of material from a public school in Cleveland, Ohio, consisted of films of both hand and foot.[6] The films used for the records of the growth of the humeral head, all from the New York children, were originally collected by Dr. Edith Lincoln (32) as a part of her study of normal hearts.

### *Technique*

The roentgenograms of the upper extremity from the New York, Merrill-Palmer, and Iowa groups gave images of the right and the left hands. Measurements were recorded for both, but since a preliminary study of the material (43) showed no real differences for number of carpals and size of the radial epiphysis and diaphysis, the averages for only one hand, the left, are presented here. In the study of carpal area recently completed by Baldwin, Busby, and Garside (5), no significant difference was found between the sums of the areas of the left and right carpal bones.

One foot only was radiographed in two positions, antero-posterior and lateral. It is from the lateral films that the measurements of the distal end of the tibia were secured. The size of the tibial index is therefore not exactly comparable to the radial index because the first is derived from antero-posterior measures on a lateral film, the second from lateral measures on an antero-posterior film. In other words, a tibial index of 95 does not represent exactly the same amount of ossification of the epiphysis proportionate to diaphysial breadth as does a radial index of 95. However, in illustrating age and sex relationships and in intermembral correlations, the difference is irrelevant.

The technique used in estimating ossification and growth from the roentgenograms was very simple. Films of hand or foot were slipped under the clips of the lighted view box and measurements made with the small sliding calipers and recorded in millimeters. The diameters measured, the greatest transverse breadth of the shafts of radius and tibia at the distal extremity, the greatest transverse breadths of their respective epiphyses, and the maximum shadow of the calcaneum as it appears in a lateral view of the foot, all lay within the beam of rays practically equal to the central ray and therefore, no factor of distortion complicated the method. All measurements were made by the writer. The small steady increments with no shrinkage shown by the records of individuals over a period of five years, when measurements were made without name or age of child being known to the anthropometrist, fully established the reliability of the technique. Presence or absence of all other epiphyses and of centers for carpal and tarsal bones were recorded, the readings being checked by an assistant.

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[6] For the opportunity to measure these, the writer is deeply indebted to the generosity of Dr. T. Wingate Todd. It was also through Dr. Todd's suggestion and advice that the development of the shoulder was added to the study.

On the roentgenograms of the chest from which data concerning the shoulder were derived, the only measurements taken were two diameters of the humeral shaft (at the proximal extremity and at the middle) on a few groups to compare boys and girls of the same age. The shoulders were at the lateral borders of the films and to calculate the amount of distortion of each small age group for no purpose but the possible correlation with radial breadth was not attempted. Since the series of chest films was begun in the City and Country School five years before this study started, there was a large amount of material from individuals having no records of hands or feet. Roentgenograms showing the shoulder in an identical position were sorted according to age and sex, and these divisions were ranked by development of the epiphyses for the tuberosity and head of the humerus.

### *Reproduction of Roentgenograms*

The usual half-tone illustration made from the roentgenogram of an extremity represents nothing but a thunder cloud. Far more useful are outline tracings from the negatives. The illustrations for the present study combine the clarity of the drawing with the accuracy of the original roentgenogram. Positive prints were made and carefully compared with the negatives. The bones were outlined and stippled with India ink directly on the print, and then the print bleached white. Epiphyses were stippled at the suggestion of Dr. Richard E. Scammon. The result is as authentic as a half-tone of the print and infinitely clearer to read

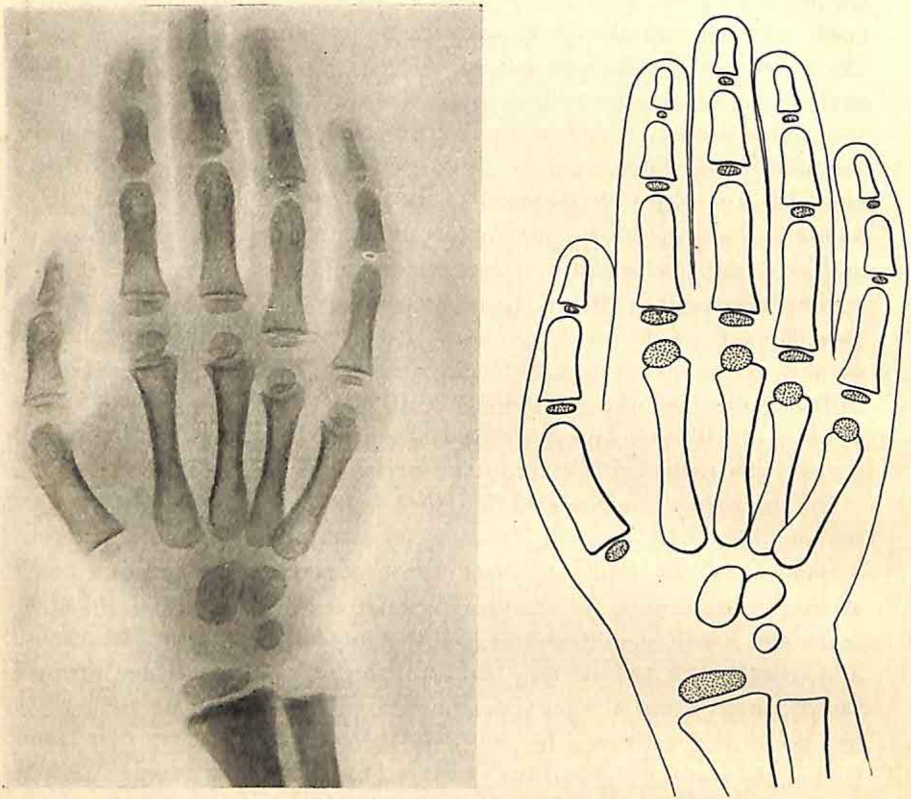

Figure 22. Two methods of reproducing the same roentgenogram

(Figure 22). All figures here reproduced are reduced to the same size.

*Age Groups*

Unlike the measurements on the body, the diameters and indices for the radius, the number of carpals and the epiphyses for metacarpals and phalanges are presented not only in groups of a year's range but, from the age of a year and a half to five and a half, they are arranged in six-month intervals as well. The exceedingly high variability evident from the standard deviations and ranges, particularly of the radial index (Tables 25 and 26), suggested that in addition to marked individual differences, there might be a close association between the index and age. Rank order correlation was therefore carried out for selected traits in various age groups. For boys of the three-year-old group, the coefficient of age and radial index was +.47 and that for stature and index +.40, whereas among the same boys, leg length with age gave only +.15 while with stature the correlation rose to +.88. For girls in the three-year range, coefficients of +.26 and +.60 were obtained for radial index with age and with stature respectively. The relationship between age and ossification as expressed by this index was not uniformly high (+.26 and +.47) but compared to the association of various parts of the body with age (for example six-year-old girls, pelvic breadth and stature +.66, pelvic breadth and age —.32), it seemed significant enough to attempt regrouping the records of the younger children in shorter age intervals. Although the results (Tables 21, 23, 25, 27, and 31) show in all but two instances, a regular progression of the averages, the standard deviations do not diminish nor do the ranges contract. In fact, the sense of individual differences in rate of ossification is intensified by the distribution into age groups of six months instead of a year interval. The relatively small amount of data concerning the ossification of the foot was therefore arranged only in twelve-month groups. As in the distribution of body measurements, 2 years=18 to 29 months.

## TRENDS OF OSSIFICATION AND BONE GROWTH

When the electric bulbs in a radiographic view box reveal the process of growth in a child's hand or foot, two things immediately stand forth. These are the light, irregular patches of ossification appearing in the center of the invisible cartilaginous masses, and in contrast, the clearly defined outlines and denser surfaces of the long bone shafts. Just this visual difference characterizes the actual development. The diaphyses of radius, tibia, and humerus, after the first rapid growth period ends at two years, add regularly to their breadth about a millimeter a year. Whereas ossification proceeds by spurt and lag and is characterized by a high degree of individual variation, the average diaphysis for boys is uniformly larger than for girls, the early establishment of the adult relationship, which has already been noted in diameters of the skull. The spread of ossification in the cartilaginous epiphyses of these bones is always in favor of the girls, an expression of the general acceleration which is most strikingly evident in the earlier onset of puberty. Not only are epiphyses for long bones larger than those of boys at an equal age; they appear considerably earlier as do also the centers for carpal and tarsal bones.

The factors governing the behavior of carpals, tarsals, epiphyses, and diaphyses during the growth period from two to eight years are age, sex, race, economic status, the individual's total size as measured by stature, and, very possibly, function. Age differences in size of centers of ossification are obvious; age differences in rate are evident and dependent on all the other factors. Sex differences begin, according to Adair and Scammon (1), in intrauterine life, the frequency of ossification of the superior tibial epiphysis, the inferior femoral epiphysis, and the cuboid bone being higher among female fetuses and newborn children than among the males of equal body length. In children from two to eight years, female ossification continues to predate that of the male.

Race differences doubtless exist but the proof does not, as yet. The effect of the dissimilarity of European stocks composing the New York, Merrill-Palmer and Iowa Child Welfare Research Station groups is even less evident in average ossification than it was in stature. The economic status of these three groups is closely comparable; the public school series from Cleveland and Atlanta show no retardation below the averages of the favored children. Stettner's (51) study of normal Erlangen children divided into three social classes each of which had three subdivisions according to stature, showed a regular progression from short country children to tall city children of prosperous parents, but the small number of cases and long age ranges in each group make his conclusions only suggestions. That, however, there is a tendency for spreading ossification and growth in breadth of bone to proceed according to stature from a late fetal stage to at least eight years is evident from Adair and Scammon's (1) grouped series, the correlations of the carpal areas by Baldwin, Busby, and Garside (5) and of various traits in the present study (Table 41). The relationship, while less dependent than that of stature and the length of long bones, is nevertheless always positive and significant.

To the clouded and controversial question of the importance of function in bone development, the greater proportion of temporary irregularities of ossification in the foot than in the hand make their silent contribution.

### THE HAND

It is not strange that in the thirty-five years since the discovery of the roentgen ray it should have been applied most often to the human wrist. The ease with which roentgenograms of the wrist can be made successfully, and the multiplicity of centers of ossification present in early life, made it seem peculiarly adapted to purposes practical and speculative. Surgeons thus obtained a clear picture of a joint frequently fractured; from the changes in the distal portions of the diaphyses of radius and ulna, pediatricians could diagnose the presence and stage of rickets, and the great variability in size and number of centers for the carpal bones present at a given age—the quality which might indicate their relative insignificance in the development of the child—seemed to offer to psychologists an individual physiologic index to relate with mental age. For some years, a curious kind of palmistry flourished. Enthusiastic ladies bending above a roentgenogram depicting the wide open spaces in the wrist of a sturdy boy of twenty months would exclaim, "How can he ever do *anything* with just those two little tiny bones!" thus overlooking the really excellent properties of cartilage. Attempts were made to unite by exact mathematical formulae the area of carpal bones ascertained in a variety of ways and a child's emotional maturity as estimated by his teacher. Coefficients of correlation were low.

Turning to the purely physical considerations, we find that the pioneer study of joints by roentgen ray, that of Poland,[7] dealt exclusively with the wrist and hand. Then in 1905 and 1908, Pryor (38) and Rotch (41) began their long series of publications devoted to the ossification and development of the wrist and the grading of roentgenograms. Both men used the method of inspection alone, but whereas Rotch eliminated age and sex and classified roentgenograms only on the basis of carpal development with the heads of metacarpals and phalanges as controls in three of his thirteen groups, Pryor continually emphasized the marked acceleration of the female in the development of centers for the carpus and the epiphyses of the hand from appearance in the embryo to union with diaphyses after puberty.

Two current studies of sound scientific conception and method are the quantitative study of ossified carpal area recently published by Baldwin, Busby, and Garside (5) and the qualitative investigation of differentiation in various parts of the hand being carried on by Dr. T. Wingate Todd at the Western Reserve Medical School.[8] The results of Baldwin, Busby, and Garside as compared with those of our series will be discussed in connection with separate traits.

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[7] Cited by Cohn, Isadore: Normal Bones and Joints Roentgenologically Considered. Annals Roentgenol., 1924, 4, No. 2.

[8] Unpublished study.

The quantitative method used in the present study was first employed when a trial balance of the data was taken, three years ago (43). An extended survey of the roentgenograms of the hand, with the intention of selecting certain characters common to all ages which might be linked with such other physiologic factors as total body size strongly suggested two conclusions which the completed study seems to substantiate: the erratic character of early ossification in carpal centers and the more orderly and relevant development of the epiphyses for the metacarpals, phalanges, and the distal extremities of the radius and ulna. This statement is most strikingly illustrated in the children from the City and Country School from two to four years of age who are known to have suffered from early malnutrition. Carpal centers often appear of a size and number above the average, but the epiphysis for the radius is small in relation to its diaphysis, and between the metacarpals and the rows of phalanges, there are a remarkable number of gaps. In the roentgenograms reproduced in Figure 23

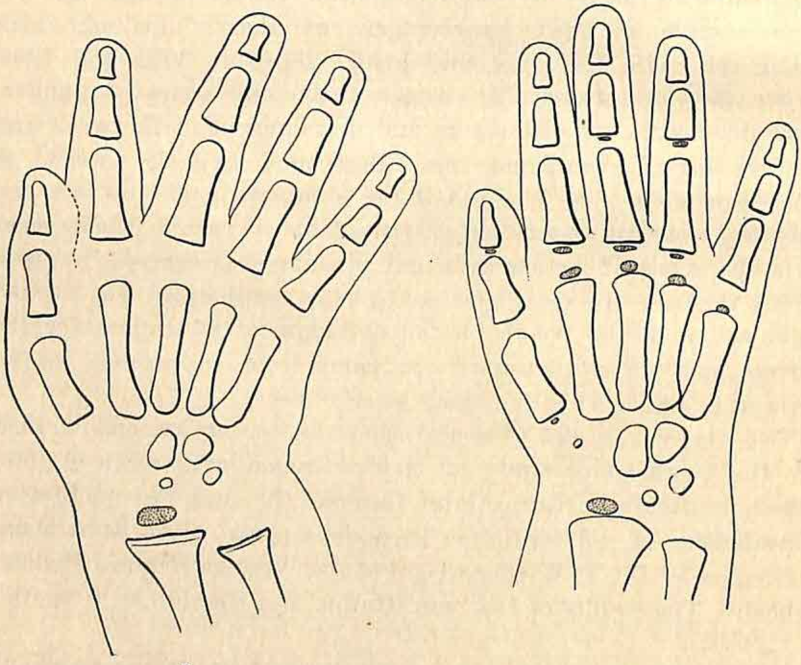


Figure 23. Accelerated carpal development and delayed ossification of epiphyses. a. Boy sixteen months, with healing rickets; b. Girl, twenty-three months

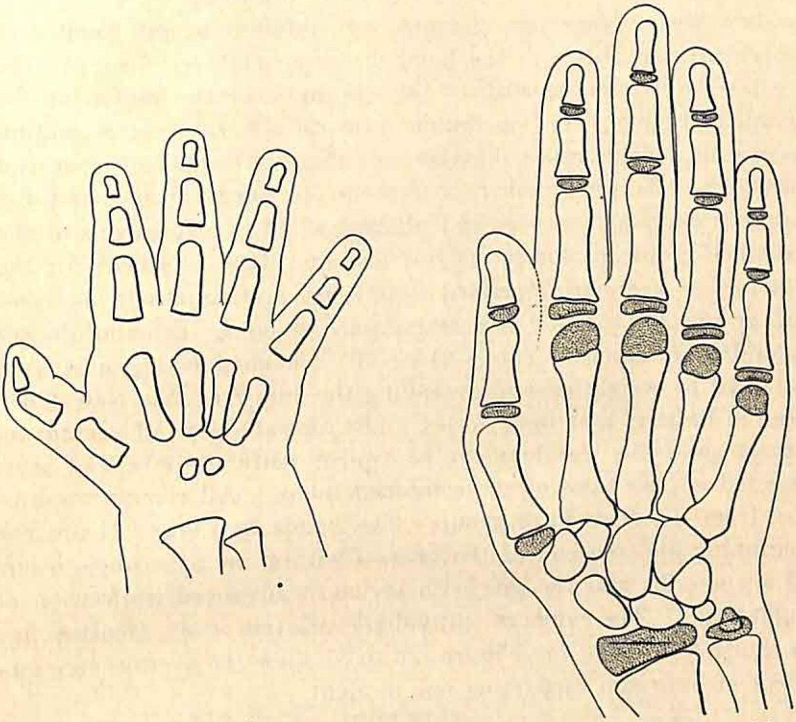


Figure 24. Ossification in the hand of a boy six months and a girl eight years of age

accelerated carpal development associated with delayed ossification of the epiphyses is illustrated by a tall boy of sixteen months with healing rickets and a short, normal girl of twenty-three months.

The epiphyses of the hand and wrist available for study were the nineteen centers for metacarpals and phalanges, evidently significant, but only for the earliest years of this series; the distal epiphysis of the ulna, which rarely appears before five years of age, is most irregular throughout the eight year groups, and does not enter directly into the articulation and function of the wrist; and the distal epiphysis of the radius. The last, present in all but four films used in the series, shows steady development and consistent age and sex differences from one to eight years. It provides, in the approach of its maximum transverse diameter to that of the diaphysis, an excellent index of spread of ossification to growth of bone; and since the ratio does not reach 100 until after the age of eight years, it is a useful tool throughout the period.

The list of traits measured, recorded, and calculated in order to show the average age changes, sex differences, and degree of individual variability in the hand of young children are: (1) the greatest transverse breadth of the diaphysis of the radius at the distal extremity, the maximum breadth of the corresponding epiphysis, and the index derived from the relationship of these two measures; (2) the number of centers for carpal bones and for epiphyses for metacarpals and phalanges; (3) the presence of the proximal epiphysis for the radius and the distal epiphysis for the ulna. The averages, standard deviations, and ranges in age and sex groups for the first two traits and percentage calculations for the third are given in Tables 21 to 33. The combined groups were obtained by weighting and averaging the data from the New York, Merrill-Palmer, and Iowa series. The reproductions of roentgenograms show the development of twelve pairs of boys and girls selected on the basis of the combined tables. All roentgenograms are from the New York group. The hands in Figure 24 are the beginning and the end of the process within our age range, a boy of six months and the girl with the most advanced ossification at eight years. The range of individual variation at an identical age is shown in Figure 25. Figures 26 to 37 show the average development of boys and girls from one to eight.

TABLE 21

Diaphysis of the Radius: Mean, Standard Deviation and Range in Millimeters of the Greatest Transverse Diameter by Year and Half-Year Age Groups for the Combined Group of Children

| Age, Years | Boys |  |  |  | Girls |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| Year Groups |  |  |  |  |  |  |  |  |
| 1 | 47 | 15.9 | 1.30 | 12 — 18 | 40 | 14.4 | 1.57 | 7 — 18 |
| 2 | 64 | 18.0 | 1.01 | 16 — 21 | 48 | 16.9 | 1.13 | 14 — 19 |
| 3 | 104 | 18.9 | 1.34 | 16 — 22 | 117 | 18.2 | 1.12 | 16 — 22 |
| 4 | 123 | 19.9 | 1.50 | 16 — 24 | 133 | 18.8 | 1.25 | 16 — 22 |
| 5 | 122 | 20.8 | 1.52 | 17 — 24 | 132 | 19.8 | 1.33 | 17 — 24 |
| 6 | 78 | 21.4 | 1.30 | 18 — 24 | 79 | 20.4 | 1.34 | 18 — 24 |
| 7 | 64 | 22.4 | 1.24 | 19 — 26 | 57 | 21.3 | 1.41 | 19 — 25 |
| 8 | 73 | 22.7 | 1.73 | 19 — 27 | 53 | 21.9 | 1.55 | 19 — 26 |
| Half-Year Groups |  |  |  |  |  |  |  |  |
| 1½ to 2 | 16 | 17.4 | 0.86 | 16 — 19 | 18 | 16.7 | 1.46 | 15 — 18 |
| 2 to 2½ | 48 | 18.2 | 0.97 | 16 — 21 | 30 | 16.8 | 1.56 | 11 — 19 |
| 2½ to 3 | 44 | 18.7 | 0.98 | 16 — 21 | 34 | 18.1 | 1.09 | 16 — 21 |
| 3 to 3½ | 57 | 19.1 | 1.27 | 16 — 22 | 80 | 18.2 | 1.15 | 16 — 22 |
| 3½ to 4 | 63 | 19.7 | 1.44 | 17 — 24 | 61 | 18.5 | 1.20 | 16 — 21 |
| 4 to 4½ | 56 | 20.2 | 1.52 | 16 — 23 | 67 | 19.0 | 1.23 | 16 — 22 |
| 4½ to 5 | 59 | 20.8 | 1.42 | 17 — 24 | 58 | 19.9 | 1.27 | 17 — 23 |
| 5 to 5½ | 47 | 20.8 | 1.48 | 17 — 24 | 63 | 19.9 | 1.38 | 17 — 24 |

TABLE 22

Diaphysis of the Radius: Mean, Standard Deviation, and Range in Millimeters of the Greatest Transverse Breadth for the New York Private School, Merrill-Palmer Nursery School and the Iowa Child Welfare Research Station Children

| Age, Years | New York Private Schools | | | | Merrill-Palmer School | | | | Iowa Child Welfare Research Station | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | | Boys | | | | | | | |
| 1 | 19 | 15.8 | 1.22 | 14 — 18 | | | | | 28 | 16.0 | 1.35 | 13 — 18 |
| 2 | 25 | 17.9 | 0.84 | 16 — 20 | 18 | 18.7 | 0.93 | 17 — 21 | 21 | 17.5 | 0.90 | 16 — 19 |
| 3 | 36 | 18.8 | 0.92 | 17 — 21 | 40 | 19.3 | 1.31 | 16 — 22 | 28 | 18.6 | 1.05 | 16 — 21 |
| 4 | 38 | 19.5 | 1.41 | 16 — 23 | 49 | 20.4 | 1.60 | 17 — 24 | 36 | 19.8 | 1.27 | 17 — 23 |
| 5 | 47 | 20.8 | 1.46 | 17 — 24 | 34 | 21.0 | 1.44 | 18 — 24 | 41 | 20.4 | 1.60 | 17 — 23 |
| 6 | 36 | 21.4 | 1.32 | 18 — 24 | | | | | 42 | 21.5 | 1.28 | 18 — 24 |
| 7 | 23 | 22.9 | 1.15 | 21 — 26 | | | | | 41 | 22.1 | 1.20 | 19 — 24 |
| 8 | 20 | 23.1 | 1.92 | 20 — 27 | | | | | 53 | 22.6 | 1.59 | 19 — 26 |
| 9 | 18 | 23.9 | 1.96 | 20 — 28 | | | | | | | | |
| | | | | | Girls | | | | | | | |
| 1 | 11 | 15.6 | 1.50 | 7 — 17 | | | | | 29 | 14.0 | 1.38 | 12 — 18 |
| 2 | 21 | 16.7 | 1.12 | 14 — 19 | 8 | 17.2 | 0.83 | 16 — 18 | 19 | 16.9 | 1.21 | 14 — 18 |
| 3 | 33 | 18.0 | 0.95 | 16 — 20 | 50 | 18.3 | 1.19 | 16 — 22 | 34 | 18.1 | 1.13 | 16 — 21 |
| 4 | 39 | 18.9 | 1.30 | 16 — 22 | 54 | 19.1 | 1.12 | 17 — 22 | 40 | 18.3 | 1.22 | 16 — 21 |
| 5 | 46 | 19.8 | 1.48 | 17 — 24 | 35 | 20.3 | 1.32 | 18 — 23 | 51 | 19.6 | 1.09 | 17 — 22 |
| 6 | 39 | 20.7 | 1.28 | 18 — 24 | | | | | 40 | 20.1 | 1.33 | 18 — 23 |
| 7 | 23 | 21.7 | 1.39 | 19 — 25 | | | | | 34 | 21.0 | 1.35 | 19 — 23 |
| 8 | 16 | 23.0 | 1.58 | 19 — 26 | | | | | 37 | 21.4 | 1.26 | 19 — 24 |
| 9 | 24 | 22.2 | 1.75 | 19 — 26 | | | | | | | | |

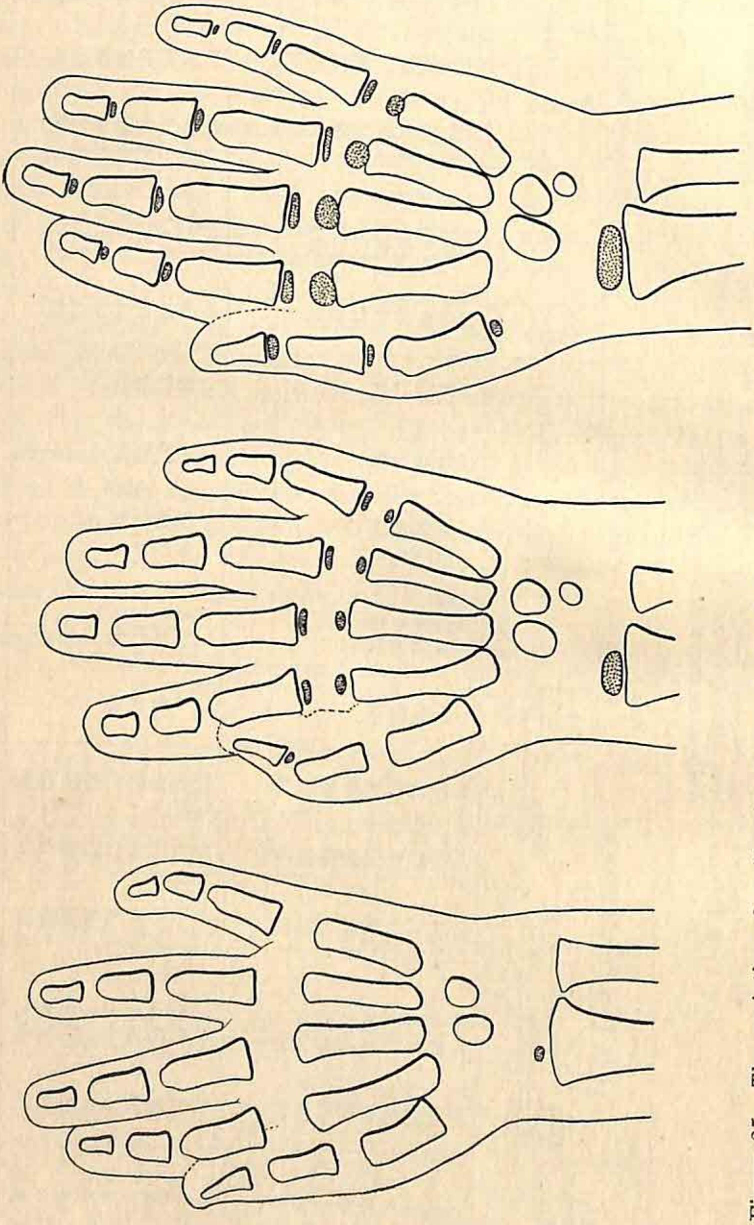


Figure 25. The variation of ossification in the hands of three boys at exactly two years of age. The middle figure shows the average development for age and sex

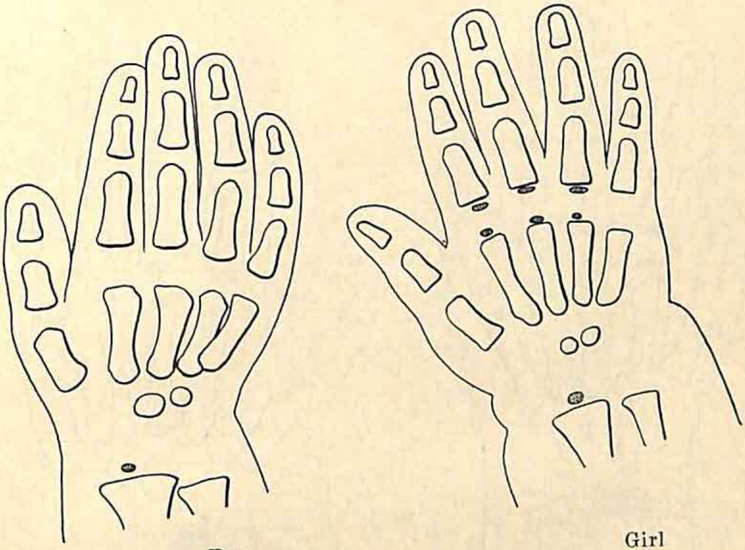


Figure 26. Average ossification at twelve months

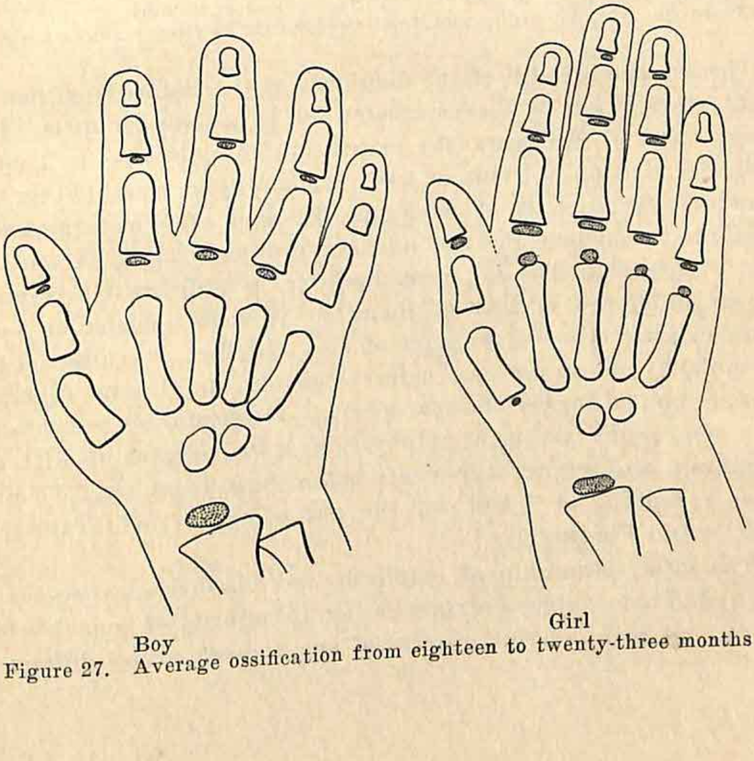


Figure 27. Average ossification from eighteen to twenty-three months

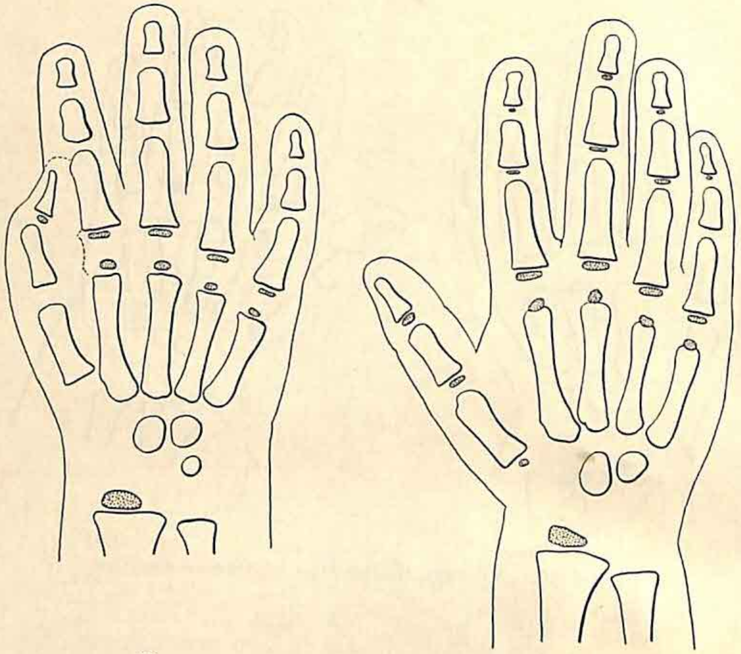
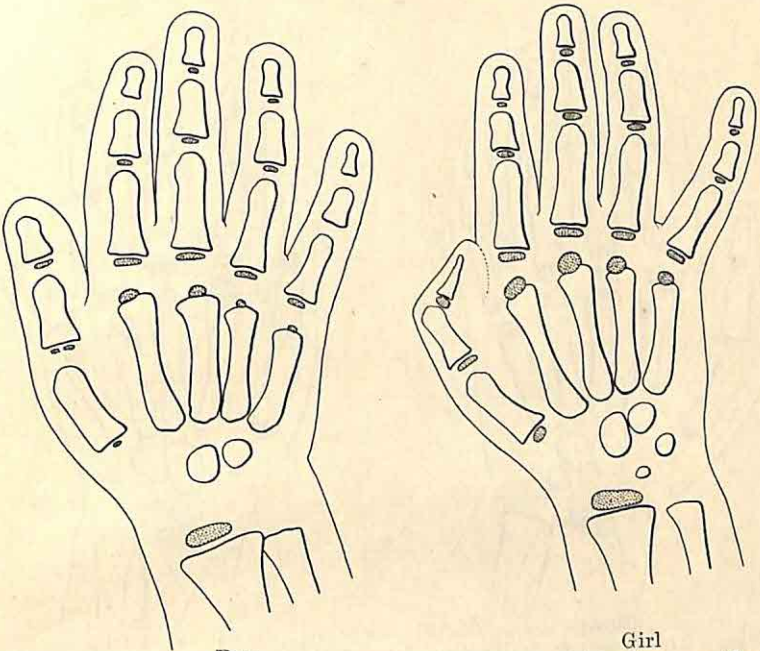


Figure 28. Average ossification from twenty-four to twenty-nine months.

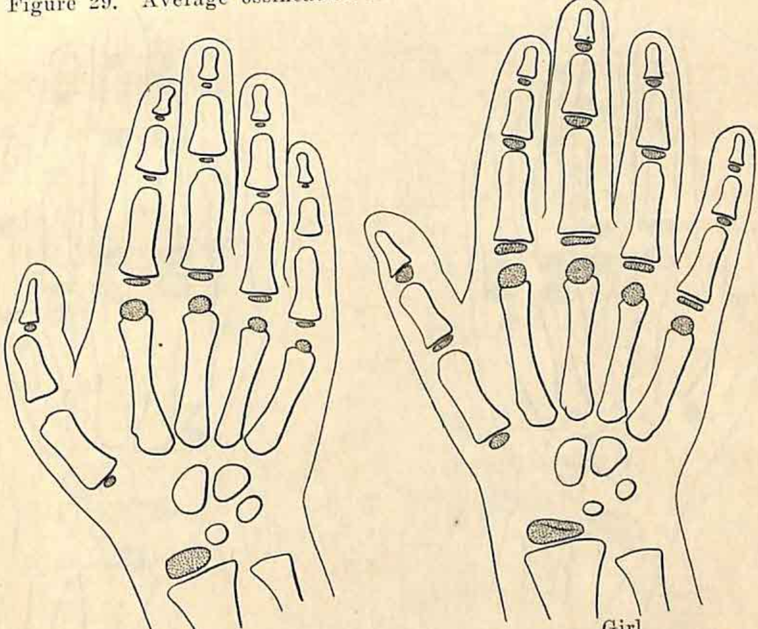
The average breadth of the diaphysis of the radius from one to eight years of age is always greater for boys than for girls. Between one and two years, the increment for both sexes is 2 mm., thereafter falling to 1 mm. or less. Variability as measured by the standard deviation is of moderate size and remains practically uniform throughout the age and sex groups (Tables 21 and 22 and Figure 38). The epiphysis, however, in addition to a reversal of sex difference in average diameter, is more variable in boys than in girls between the ages of two and five. Because of the irregularity of appearance before eighteen months, no averages were computed for the one-year groups. Ossification is progressing at a more rapid rate in the epiphysis, as it has to catch up with the diaphysis, and annual increments before four years are 2.5 and 3 mm., remaining at 2 mm. for the rest of the period (Tables 23 and 24 and Figure 39).

The interrelationship of epiphysis and diaphysis, expressed as the radial index, gives a certain rating of maturity of bone development, and as a descriptive term of age and sex group difference,



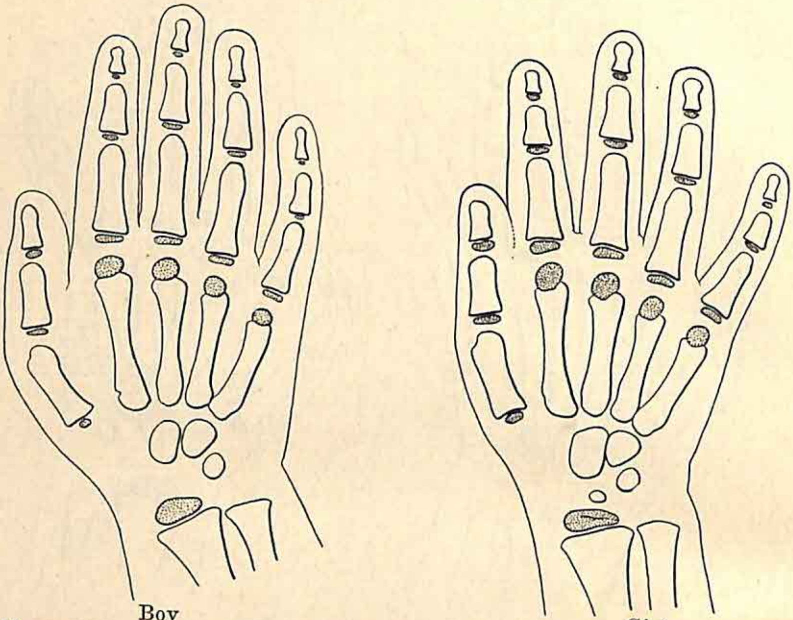
Boy Girl

Figure 29. Average ossification from thirty to thirty-five months



Boy Girl

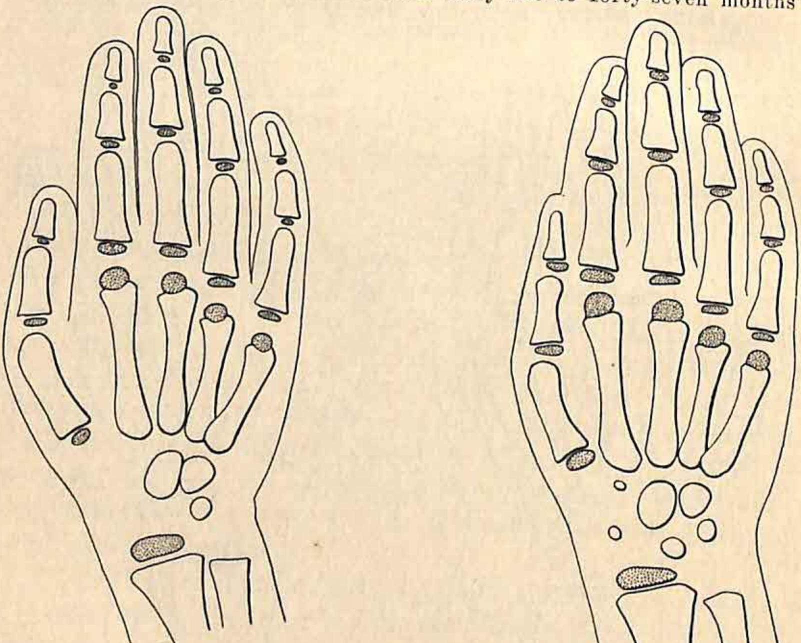
Figure 30. Average ossification from thirty-six to forty-one months



Boy

Girl

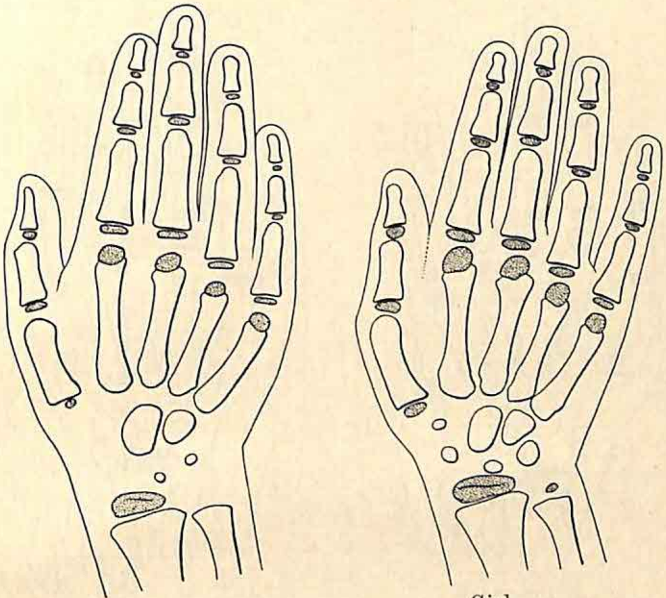
Figure 31. Average ossification from forty-two to forty-seven months



Boy

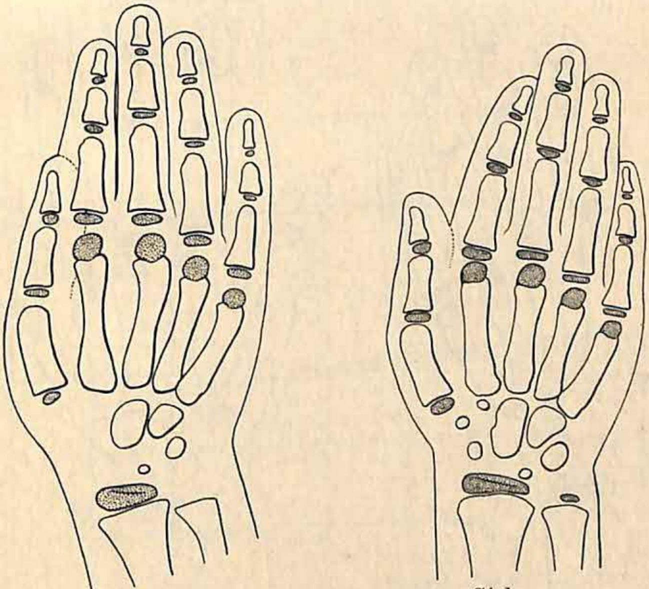
Girl

Figure 32. Average ossification from forty-eight to fifty-three months



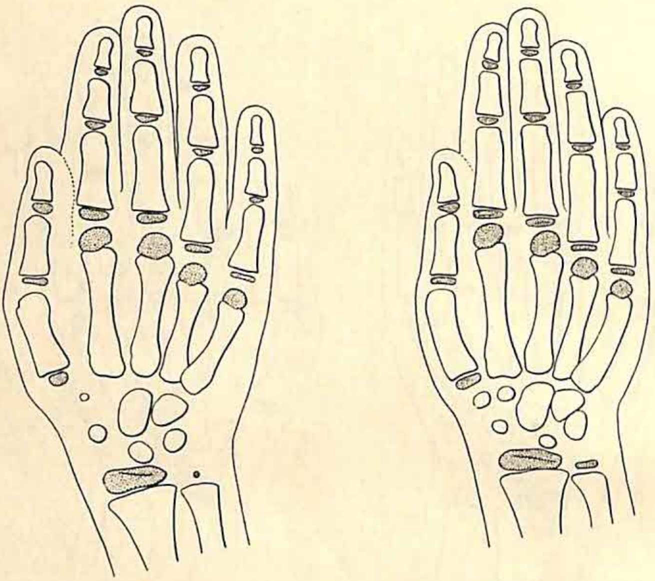
Boy Girl

Figure 33. Average ossification from fifty-four to fifty-nine months



Boy Girl

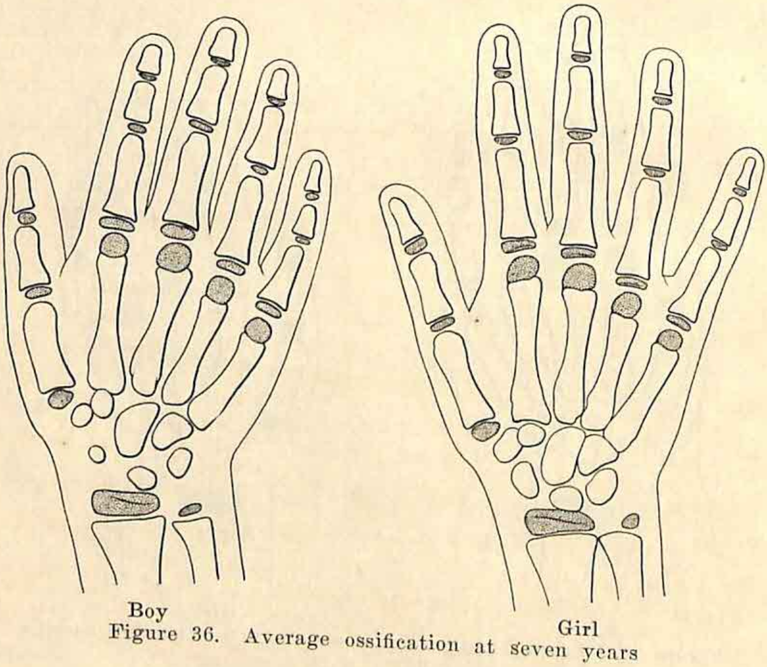
Figure 34. Average ossification from sixty to sixty-five months



Boy

Girl

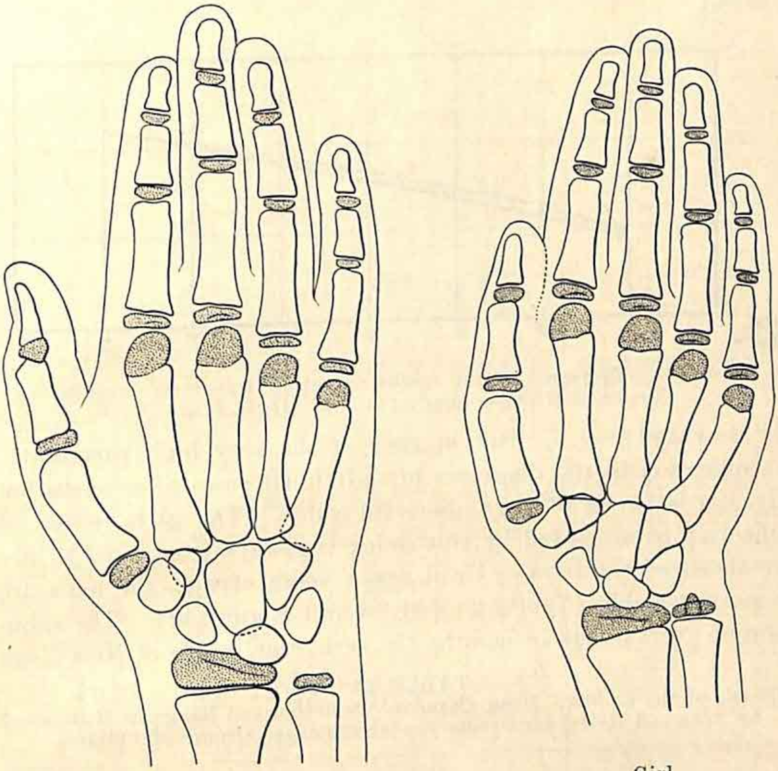
Figure 35. Average ossification at six years



Boy

Girl

Figure 36. Average ossification at seven years



Boy

Girl

Figure 37. Average ossification at eight years

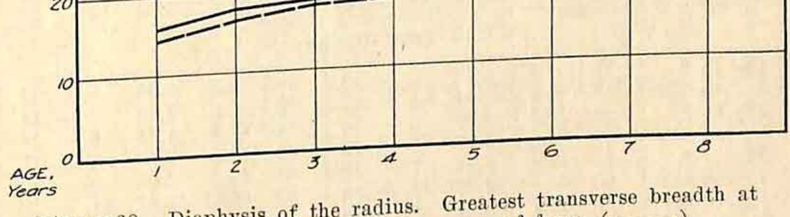


Figure 38. Diaphysis of the radius. Greatest transverse breadth at distal extremity. Combined groups of boys (———) and girls (- - - -)

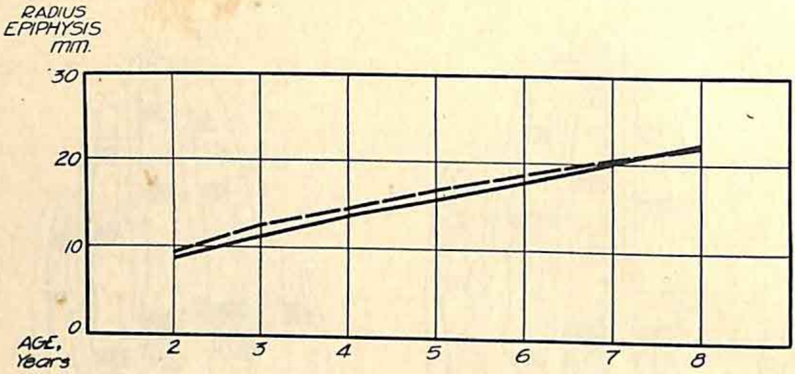


Figure 39. Epiphysis of the radius. Greatest transverse breadth. Combined Groups. Boys (———), Girls (- - - -)

it is clear and useful. But in view of the very high variability, its application in the diagnosis of individual cases of acceleration and retardation is of very doubtful value. The girls' stage of ossification as measured by this index is always from 8 to 10 per cent ahead of the boys'. Until seven years of age, the boys are the more variable (Tables 25 and 26 and Figure 40). The tabulation of average age in months for each year group of New York

TABLE 23
Epiphysis of the Radius: Mean, Standard Deviation and Range in Millimeters by Year and Half-Year Groups for the Combined Groups of Children

| Age, Years | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| Year Groups | | | | | | | | |
| 2 | 64 | 8.8 | 3.46 | 1 — 15 | 48 | 9.3 | 2.26 | 3 — 13 |
| 3 | 105 | 11.3 | 3.16 | 0 — 19 | 117 | 12.6 | 2.03 | 5 — 17 |
| 4 | 123 | 13.9 | 2.58 | 3 — 19 | 133 | 14.7 | 1.98 | 9 — 19 |
| 5 | 122 | 15.7 | 2.51 | 9 — 21 | 132 | 17.0 | 1.76 | 12 — 21 |
| 6 | 78 | 17.9 | 1.88 | 13 — 22 | 79 | 18.6 | 1.85 | 15 — 22 |
| 7 | 64 | 20.2 | 1.78 | 15 — 24 | 57 | 20.4 | 1.68 | 17 — 24 |
| 8 | 74 | 22.3 | 1.59 | 19 — 26 | 53 | 21.8 | 1.72 | 18 — 26 |
| Half-Year Groups | | | | | | | | |
| 1½ to 2 | 16 | 7.5 | 3.12 | 2 — 13 | 18 | 8.3 | 2.56 | 3 — 13 |
| 2 to 2½ | 48 | 9.2 | 3.44 | 1 — 15 | 30 | 9.9 | 1.50 | 7 — 13 |
| 2½ to 3 | 45 | 10.5 | 2.98 | 0 — 15 | 34 | 12.3 | 1.84 | 8 — 16 |
| 3 to 3½ | 57 | 11.8 | 3.19 | 0 — 19 | 80 | 12.7 | 2.13 | 5 — 17 |
| 3½ to 4 | 63 | 13.4 | 2.31 | 7 — 18 | 61 | 14.1 | 2.07 | 9 — 19 |
| 4 to 4½ | 56 | 14.3 | 2.78 | 3 — 19 | 67 | 15.2 | 1.81 | 11 — 19 |
| 4½ to 5 | 59 | 16.1 | 2.14 | 9 — 19 | 58 | 16.6 | 1.84 | 12 — 20 |
| 5 to 5½ | 47 | 16.4 | 2.48 | 13 — 21 | 63 | 17.3 | 1.65 | 14 — 21 |

TABLE 24

Epiphysis of the Radius: Mean, Standard Deviation and Range of the Maximum Breadth in Millimeters for the New York Private School, Merrill-Palmer Nursery School and the Iowa Child Welfare Research Station Children

| Age, Years | New York Private School | | | | Merrill-Palmer School | | | | Iowa Child Welfare Research Station | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | | Boys | | | | | | | |
| 1 | 25 | 8.6 | 3.31 | 2 — 13 | | | | | | | | |
| 2 | 36 | 11.6 | 2.32 | 6 — 16 | 18 | 10.1 | 2.44 | 6 — 14 | 21 | 8.0 | 4.02 | 1 — 15 |
| 3 | 38 | 13.7 | 2.60 | 9 — 19 | 40 | 11.4 | 3.60 | 0 — 16 | 29 | 10.8 | 3.37 | 3 — 19 |
| 4 | 47 | 15.0 | 2.71 | 11 — 21 | 49 | 14.0 | 2.86 | 3 — 18 | 36 | 13.9 | 2.11 | 9 — 17 |
| 5 | 36 | 17.4 | 1.93 | 13 — 21 | 34 | 16.4 | 2.43 | 9 — 20 | 41 | 16.0 | 2.08 | 11 — 19 |
| 6 | 23 | 20.6 | 2.08 | 15 — 24 | | | | | 42 | 18.3 | 1.73 | 14 — 22 |
| 7 | 20 | 22.2 | 1.84 | 19 — 26 | | | | | 41 | 20.0 | 1.55 | 17 — 24 |
| 8 | 18 | 23.9 | 2.28 | 19 — 28 | | | | | 54 | 22.3 | 1.48 | 19 — 25 |
| | | | | | Girls | | | | | | | |
| 1 | 21 | 9.4 | 1.94 | 7 — 13 | | | | | | | | |
| 2 | 33 | 12.3 | 1.88 | 8 — 17 | 8 | 8.9 | 1.96 | 6 — 11 | 19 | 9.5 | 2.64 | 3 — 13 |
| 3 | 39 | 14.9 | 1.88 | 12 — 18 | 50 | 12.9 | 1.94 | 9 — 16 | 34 | 12.4 | 2.25 | 5 — 17 |
| 4 | 46 | 17.1 | 1.73 | 13 — 21 | 54 | 15.2 | 1.86 | 10 — 19 | 40 | 13.6 | 1.82 | 9 — 17 |
| 5 | 39 | 18.7 | 1.50 | 15 — 22 | 35 | 17.4 | 1.69 | 13 — 20 | 51 | 16.6 | 1.75 | 12 — 21 |
| 6 | 23 | 20.4 | 1.76 | 17 — 24 | | | | | 40 | 18.6 | 1.61 | 15 — 22 |
| 7 | 16 | 22.8 | 1.82 | 19 — 26 | | | | | 34 | 20.4 | 1.61 | 17 — 23 |
| 8 | 24 | 23.1 | 1.78 | 19 — 26 | | | | | 37 | 21.3 | 1.47 | 18 — 26 |

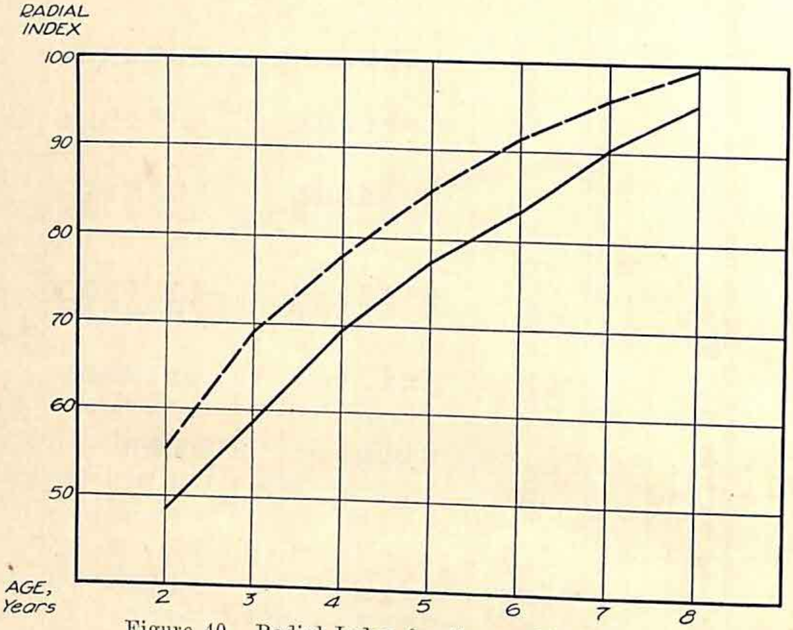


Figure 40. Radial Index for the combined group.
Boys (———), Girls (- - - -)

TABLE 25

Radial Index: Mean, Standard Deviation and Range by Year and Half-Year Age Groups for the Combined Groups of Children

| Age, Years | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Year Groups | | | | |
| 2 | 64 | 48.4 | 18.21 | 6 — 84 | 48 | 55.3 | 14.46 | 19 — 77 |
| 3 | 104 | 58.8 | 11.87 | 0 — 90 | 117 | 69.1 | 10.03 | 26 — 89 |
| 4 | 123 | 69.6 | 11.73 | 16 — 90 | 133 | 78.1 | 8.93 | 47 — 95 |
| 5 | 122 | 77.4 | 9.99 | 43 — 95 | 132 | 85.6 | 7.67 | 47 —100 |
| 6 | 78 | 83.3 | 7.33 | 67 —100 | 79 | 91.6 | 6.96 | 70 —106 |
| 7 | 64 | 90.4 | 6.24 | 68 —105 | 57 | 96.0 | 6.52 | 76 —105 |
| 8 | 73 | 95.5 | 4.94 | 84 —110 | 53 | 99.4 | 5.60 | 81 —115 |
| | | | | Half-Year Groups | | | | |
| 1½ to 2 | 16 | 42.7 | 18.17 | 12 — 81 | 18 | 49.6 | 14.04 | 19 — 76 |
| 2 to 2½ | 48 | 50.2 | 18.19 | 11 — 83 | 30 | 58.7 | 9.84 | 39 — 76 |
| 2½ to 3 | 47 | 55.4 | 14.75 | 0 — 78 | 34 | 67.8 | 8.24 | 47 — 84 |
| 3 to 3½ | 58 | 61.4 | 7.70 | 0 — 90 | 82 | 69.9 | 10.91 | 26 — 89 |
| 3½ to 4 | 65 | 68.2 | 10.82 | 35 — 89 | 62 | 76.3 | 8.91 | 47 — 94 |
| 4 to 4½ | 58 | 71.2 | 12.51 | 16 — 90 | 70 | 79.6 | 8.75 | 55 — 95 |
| 4½ to 5 | 67 | 77.3 | 9.64 | 43 — 95 | 65 | 83.8 | 8.24 | 57 —100 |
| 5 to 5½ | 54 | 79.8 | 8.83 | 50 — 95 | 67 | 87.3 | 6.67 | 64 —100 |

TABLE 26

Radial Index: Mean, Standard Deviation and Range for the New York Private School, Merrill-Palmer Nursery School and the Iowa Child Welfare Research Station Children

| Age, Years | New York Private School | | | | Merrill-Palmer School | | | | Iowa Child Welfare Research Station | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | | Boys | | | | | | | |
| 1 | 25 | 47.4 | 17.70 | 11 — 72 | | | | | | | | |
| 2 | 36 | 60.6 | 11.56 | 33 — 75 | 18 | 53.4 | 11.20 | 33 — 74 | 21 | 45.1 | 22.28 | 6 — 83 |
| 3 | 38 | 70.2 | 11.64 | 43 — 90 | 40 | 58.3 | 7.35 | 0 — 80 | 28 | 57.0 | 16.32 | 18 — 90 |
| 4 | 47 | 76.1 | 10.30 | 50 — 95 | 49 | 68.7 | 12.50 | 16 — 89 | 36 | 70.3 | 10.59 | 41 — 89 |
| 5 | 36 | 81.4 | 7.56 | 68 — 95 | 34 | 78.3 | 11.18 | 43 — 95 | 41 | 78.2 | 8.28 | 65 — 95 |
| 6 | 23 | 90.0 | 8.36 | 68 —105 | | | | | 42 | 84.9 | 6.72 | 67 —100 |
| 7 | 20 | 96.5 | 5.17 | 84 —110 | | | | | 41 | 90.6 | 4.61 | 81 —100 |
| 8 | 18 | 98.9 | 6.52 | 86 —113 | | | | | 53 | 95.1 | 4.80 | 86 —110 |
| | | | | | Girls | | | | | | | |
| 1 | 11 | 30.4 | 18.11 | 13 — 69 | | | | | | | | |
| 2 | 21 | 56.4 | 10.90 | 39 — 71 | 8 | 51.6 | 11.80 | 37 — 69 | 19 | 55.6 | 13.83 | 19 — 76 |
| 3 | 33 | 68.2 | 9.65 | 47 — 89 | 50 | 70.2 | 8.98 | 50 — 89 | 34 | 68.4 | 11.59 | 26 — 88 |
| 4 | 39 | 79.0 | 8.81 | 55 — 95 | 54 | 79.8 | 7.91 | 52 — 95 | 40 | 74.8 | 9.45 | 47 — 94 |
| 5 | 46 | 86.3 | 7.11 | 64 —100 | 35 | 85.8 | 7.69 | 62 —100 | 51 | 84.8 | 8.06 | 57 —100 |
| 6 | 39 | 90.5 | 6.82 | 70 —100 | | | | | 40 | 92.6 | 6.94 | 79 —106 |
| 7 | 23 | 94.3 | 7.03 | 76 —105 | | | | | 34 | 97.1 | 5.89 | 81 —105 |
| 8 | 16 | 99.0 | 6.29 | 81 —109 | | | | | 37 | 99.6 | 5.27 | 90 —115 |
| 9 | 24 | 104.6 | 5.52 | 88 —116 | | | | | | | | |

children given below shows that a younger average age among the girls does not mean a lower average index.

| Age, Years | Age, Months | |
|---|---|---|
| | Boys | Girls |
| 1 | 19.4 | 13.1 |
| 2 | 25.3 | 24.7 |
| 3 | 34.9 | 36.8 |
| 4 | 47.8 | 48.3 |
| 5 | 59.8 | 59.8 |
| 6 | 71.4 | 71.3 |
| 7 | 84.2 | 83.7 |
| 8 | 94.4 | 96.4 |

The same conditions of sex and age govern the appearance of epiphyses for the metacarpals and phalanges. Almost all girls over twenty-nine months have the complete set of nineteen present, but the boys do not arrive at this state before the age of five years. The most striking sex difference is shown by the New York children of one year where the averages of age and epiphyses are: boys 19.4 months, 1.7 epiphyses, girls 13.1 months, 5.6 epiphyses. The variability naturally decreases rapidly with age as the standard deviation approaches zero (Tables 27 and 28).

The proximal epiphysis for the radius appears at three years in both girls and boys but until eight years, a higher per cent is present in each feminine age group (Table 29). In neither sex at eight years is this epiphysis present in all individuals.

TABLE 27

Epiphyses for Metacarpals and Phalanges: Mean, Standard Deviation and Range of Number Present by Year and Half-Year Age Groups for the Combined Group of Children

| Age, Years | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| Year Groups | | | | | | | | |
| 2 | 62 | 9.7 | 4.80 | 0 — 19 | 47 | 16.4 | 3.60 | 5 — 19 |
| 3 | 103 | 16.5 | 2.78 | 7 — 19 | 115 | 18.8 | 0.65 | 13 — 19 |
| 4 | 118 | 18.2 | 1.54 | 12 — 19 | 128 | 19.0 | 0.33 | 16 — 19 |
| 5 | 106 | 18.9 | 0.53 | 17 — 19 | 86 | 19.0 | 0.00 | 19 — 19 |
| 6 | 70 | 19.0 | 0.24 | 17 — 19 | | | | |
| 7 | 64 | 19.0 | 0.00 | 19 — 19 | | | | |
| Half-Year Groups | | | | | | | | |
| 1½ to 2 | 15 | 7.7 | 3.48 | 0 — 13 | 18 | 15.0 | 3.67 | 5 — 19 |
| 2 to 2½ | 46 | 10.7 | 4.72 | 0 — 19 | 29 | 17.2 | 3.28 | 8 — 19 |
| 2½ to 3 | 47 | 15.6 | 2.63 | 8 — 19 | 34 | 18.7 | 0.57 | 17 — 19 |
| 3 to 3½ | 56 | 17.2 | 2.71 | 7 — 19 | 80 | 18.9 | 0.69 | 13 — 19 |
| 3½ to 4 | 63 | 18.0 | 1.71 | 11 — 19 | 61 | 19.0 | 0.0 | 19 — 19 |
| 4 to 4½ | 55 | 18.4 | 1.28 | 13 — 19 | | | | |

TABLE 28

Epiphyses for Metacarpals and Phalanges: Mean, Standard Deviation and Range of Number Present in the New York Private School, Merrill-Palmer Nursery School, and the Iowa Child Welfare Research Station Children

| Age, Years | New York Private School | | | | Merrill-Palmer School | | | | Iowa Child Welfare Research Station | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| Boys | | | | | | | | | | | | |
| 2 | 19 | 1.74 | 2.92 | 0 — 8 | 16 | 11.25 | 3.98 | 5 — 17 | 21 | 8.71 | 5.09 | 3 — 19 |
| 3 | 25 | 9.44 | 4.77 | 0 — 19 | 38 | 17.45 | 1.98 | 10 — 19 | 29 | 16.14 | 2.72 | 7 — 19 |
| 4 | 36 | 15.75 | 3.21 | 8 — 19 | 48 | 18.52 | 0.96 | 15 — 19 | 36 | 18.47 | 0.98 | 15 — 19 |
| 5 | 34 | 17.47 | 2.26 | 12 — 19 | 32 | 19.00 | 0.00 | 19 — 19 | 41 | 18.95 | 0.22 | 18 — 19 |
| 6 | 33 | 18.76 | 0.55 | 17 — 19 | | | | | 42 | 18.95 | 0.30 | 17 — 19 |
| 7 | 28 | 19.00 | 0.00 | 19 — 19 | | | | | 41 | 19.00 | 0.00 | 19 — 19 |
| Girls | | | | | | | | | | | | |
| 2 | 11 | 5.56 | 5.16 | 0 — 14 | 8 | 16.50 | 3.67 | 9 — 19 | 19 | 16.58 | 3.13 | 8 — 19 |
| 3 | 20 | 16.15 | 3.95 | 5 — 19 | 50 | 18.88 | 0.38 | 18 — 19 | 34 | 18.85 | 0.43 | 17 — 19 |
| 4 | 31 | 18.74 | 1.08 | 13 — 19 | 54 | 18.98 | 0.13 | 18 — 19 | 40 | 18.88 | 0.56 | 16 — 19 |
| 5 | 34 | 19.00 | 0.00 | 19 — 19 | 35 | 19.00 | 0.00 | 19 — 19 | 51 | 19.00 | 0.00 | 19 — 19 |

The first shadow for the distal epiphysis of the ulna is seen in a very few girls at three years. It is rare in boys of five and at eight only 73 per cent have produced it whereas the presence in girls is 100 per cent (Table 30). The late appearance of this epiphysis in contrast to that of the radius close by gives rise to speculations interesting if idle. Unlike the radius, the human ulna which does not enter directly into the function of the wrist might seem to call for less development at an early age. Among anthropoid apes, however, there are indications of an earlier response. Dr. Charles V. Noback (36) of the New York Zoölogical Society has recently published roentgenograms of four young gorillas from nine to twenty-four months old, all with a distal epiphysis for the ulna proportionate in size to that of the radius.

Higher averages and smaller standard deviations for girls are characteristic of the much discussed carpal bones. There is almost no difference among the five groups, New York, Merrill-Palmer, Iowa Child Welfare Research Station, Atlanta, and Cleveland groups. The eighth bone (the pisiform) first appears in the hand of a girl six years and seven months old. No New York boy has a pisiform at nine years (Tables 31 and 33). The exact age and

TABLE 29

Proximal Epiphysis of the Radius: Per Cent of Appearance for the New York Private School and the Merrill-Palmer Nursery School Children

| Age, Years | New York Private School | | Merrill-Palmer School | |
|---|---|---|---|---|
| | Children | Per cent | Children | Per cent |
| | | Boys | | |
| 3 | 25 | 0.0 | 29 | 6.9 |
| 4 | 38 | 11.8 | 32 | 21.9 |
| 5 | 31 | 38.7 | 21 | 47.6 |
| 6 | 28 | 39.3 | | |
| 7 | 22 | 77.3 | | |
| 8 | 18 | 94.4 | | |
| 9 | 10 | 90.0 | | |
| | | Girls | | |
| 3 | 31 | 22.6 | 38 | 50.0 |
| 4 | 35 | 54.3 | 38 | 50.0 |
| 5 | 35 | 71.4 | 30 | 70.0 |
| 6 | 30 | 83.3 | | |
| 7 | 23 | 95.6 | | |
| 8 | 16 | 93.7 | | |
| 9 | 9 | 88.9 | | |

TABLE 30

Ulna, Distal Epiphysis: Per Cent of Appearance in Combined Age Groups, for the New York Private School, Merrill-Palmer, Iowa Child Welfare Research Station, and Atlanta Public School Groups

| Age, Years | Combined Averages in Year Groups | | New York Private School | | Merrill-Palmer School | | Iowa Child Welfare Research Station | | Atlanta Public Schools | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Per cent | Children | Per cent | Children | Per cent | Children | Per cent | Children | Per cent |
| | | | | | Boys | | | | | |
| 3 | 102 | 0.0 | 36 | 0.0 | 37 | 0.0 | 29 | 0.0 | | |
| 4 | 121 | 0.0 | 38 | 0.0 | 47 | 0.0 | 36 | 0.0 | | |
| 5 | 104 | 4.3 | 31 | 9.7 | 32 | 4.8 | 41 | 2.4 | 50 | 12.0 |
| 6 | 70 | 21.4 | 28 | 25.0 | | | 42 | 19.0 | 50 | 28.0 |
| 7 | 63 | 40.3 | 22 | 40.9 | | | 41 | 40.0 | 50 | 72.0 |
| 8 | 74 | 73.0 | 20 | 60.0 | | | 54 | 77.8 | 50 | 86.0 |
| | | | | | Girls | | | | | |
| 3 | 120 | 2.6 | 20 | 0.0 | 54 | 4.0 | 34 | 2.9 | | |
| 4 | 133 | 9.0 | 39 | 10.3 | 54 | 11.1 | 40 | 5.0 | | |
| 5 | 132 | 26.5 | 46 | 34.8 | 35 | 22.9 | 51 | 21.6 | 50 | 28.0 |
| 6 | 79 | 58.3 | 39 | 64.1 | | | 40 | 52.5 | 50 | 72.0 |
| 7 | 57 | 93.0 | 23 | 91.3 | | | 34 | 94.1 | 50 | 92.0 |
| 8 | 53 | 100.0 | 16 | 100.0 | | | 37 | 100.0 | 50 | 100.0 |

order of appearance for the separate carpal bones has been worked out by many authors, most recently and fully in the Iowa and New York studies previously mentioned (5), (43). In general, a bone is present in 100 per cent of the girls at least two years before the boys reach this figure. The erratic and highly individual character of the amount of carpal ossification completed at any early stage is strikingly illustrated by the study of Baldwin, Busby, and Garside ((5), page 9), where the ranges of carpal area in each group, as measured by the planimeter, are stated in terms of other age groups. For instance, in the two-year-old group, the most retarded boy has a carpal area equal to that of a four-month-old baby and the most accelerated equals the area of a five-year-old. Even supposing, since carpal area correlates fairly well with stature, that the child with the smallest area was the shortest in his group, etc., the individual variation within a normal year group is so great that diagnosis of physical maturity on the basis of carpal development alone either actual or relative is manifestly impossible.

That the amount of carpal development, the size of the radial

TABLE 31

Carpal Centers: Mean, Standard Deviation and Range in Number by Year and Half-Year Age Groups for the Combined Groups of Children

| Age, Years | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Year Groups | | | | |
| 1 | 48 | 2.2 | 0.48 | 1 — 4 | 40 | 2.2 | 0.44 | 2 — 4 |
| 2 | 64 | 2.7 | 0.79 | 1 — 4 | 49 | 2.8 | 0.82 | 2 — 5 |
| 3 | 105 | 3.1 | 0.92 | 2 — 6 | 117 | 3.7 | 1.28 | 2 — 7 |
| 4 | 121 | 3.5 | 1.20 | 2 — 7 | 133 | 4.9 | 1.57 | 2 — 7 |
| 5 | 122 | 4.2 | 1.39 | 2 — 7 | 132 | 6.1 | 1.17 | 3 — 7 |
| 6 | 78 | 5.1 | 1.56 | 2 — 7 | 79 | 6.9 | 0.43 | 5 — 8 |
| 7 | 64 | 6.2 | 1.14 | 3 — 7 | 57 | 7.1 | 0.73 | 6 — 8 |
| 8 | 74 | 6.8 | 0.52 | 5 — 7 | 53 | 7.2 | 0.36 | 7 — 8 |
| | | | | Half-Year Groups | | | | |
| 1½ to 2 | 18 | 2.4 | 0.70 | 1 — 4 | 18 | 3.0 | 0.97 | 2 — 5 |
| 2 to 2½ | 48 | 2.8 | 0.80 | 2 — 4 | 30 | 2.6 | 0.67 | 2 — 4 |
| 2½ to 3 | 47 | 3.0 | 1.06 | 2 — 6 | 34 | 3.7 | 1.16 | 2 — 7 |
| 3 to 3½ | 58 | 3.2 | 0.81 | 2 — 5 | 82 | 3.8 | 1.34 | 2 — 7 |
| 3½ to 4 | 63 | 3.3 | 1.06 | 2 — 6 | 62 | 4.8 | 1.62 | 2 — 7 |
| 4 to 4½ | 58 | 3.8 | 1.27 | 2 — 7 | 70 | 5.1 | 1.51 | 3 — 7 |
| 4½ to 5 | 67 | 4.1 | 1.45 | 2 — 7 | 65 | 6.0 | 1.26 | 3 — 7 |
| 5 to 5½ | 54 | 4.3 | 1.28 | 2 — 7 | 67 | 6.3 | 1.05 | 3 — 7 |

TABLE 32

Carpal Centers: Mean, Standard Deviation and Range in Number for New York Private School, Merrill-Palmer Nursery School, Iowa Child Welfare Research Station, and Atlanta Public School Children

| Age, Years | New York Private School | | | | Merrill-Palmer School | | | | Iowa Child Welfare Research Station | | | | Atlanta Public Schools | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | | | | | Boys | | | | | | | | |
| 1 | 20 | 2.2 | 0.54 | 2 — 4 | | | | | 28 | 2.1 | 0.44 | 1 — 3 | | | | |
| 2 | 25 | 2.7 | 0.72 | 2 — 4 | 18 | 2.8 | 0.85 | 2 — 4 | 21 | 2.5 | 0.79 | 1 — 4 | | | | |
| 3 | 36 | 3.3 | 1.02 | 2 — 6 | 40 | 3.0 | 0.77 | 2 — 5 | 29 | 2.9 | 0.94 | 2 — 5 | | | | |
| 4 | 38 | 3.5 | 1.35 | 2 — 7 | 48 | 3.6 | 0.90 | 2 — 6 | 35 | 3.5 | 1.34 | 2 — 7 | | | | |
| 5 | 47 | 4.2 | 1.41 | 2 — 7 | 34 | 4.4 | 1.41 | 2 — 7 | 41 | 4.0 | 1.30 | 2 — 7 | 50 | 5.1 | 0.33 | 4 — 7 |
| 6 | 36 | 4.9 | 1.59 | 2 — 7 | | | | | 42 | 5.2 | 1.52 | 3 — 7 | 50 | 5.8 | 0.51 | 3 — 7 |
| 7 | 23 | 6.2 | 1.25 | 3 — 7 | | | | | 41 | 6.2 | 1.08 | 3 — 7 | 50 | 6.5 | 0.65 | 3 — 7 |
| 8 | 20 | 6.8 | 0.54 | 5 — 7 | | | | | 54 | 6.8 | 0.51 | 5 — 7 | 50 | 6.7 | 0.50 | 4 — 8 |
| 9 | 18 | 7.0 | 0.00 | 7 — 7 | | | | | | | | | | | | |
| | | | | | | | | Girls | | | | | | | | |
| 1 | 11 | 2.3 | 0.44 | 2 — 3 | | | | | 29 | 2.1 | 0.43 | 2 — 4 | | | | |
| 2 | 21 | 2.9 | 0.83 | 2 — 5 | 8 | 2.4 | 0.70 | 2 — 4 | 19 | 2.8 | 0.81 | 2 — 5 | | | | |
| 3 | 33 | 3.8 | 1.29 | 2 — 7 | 50 | 3.7 | 1.25 | 2 — 7 | 34 | 3.7 | 1.31 | 2 — 7 | | | | |
| 4 | 39 | 5.0 | 1.50 | 2 — 7 | 54 | 5.2 | 1.52 | 3 — 7 | 40 | 4.5 | 1.61 | 2 — 7 | | | | |
| 5 | 46 | 6.3 | 0.90 | 4 — 7 | 35 | 6.0 | 1.30 | 3 — 7 | 51 | 6.1 | 1.28 | 3 — 7 | 50 | 6.4 | 0.60 | 3 — 7 |
| 6 | 39 | 6.9 | 0.44 | 5 — 8 | | | | | 40 | 6.8 | 0.42 | 5 — 7 | 50 | 6.8 | 0.51 | 4 — 8 |
| 7 | 23 | 7.0 | 0.36 | 6 — 8 | | | | | 34 | 7.1 | 0.28 | 7 — 8 | 50 | 7.1 | 0.13 | 7 — 8 |
| 8 | 16 | 7.1 | 0.33 | 7 — 8 | | | | | 37 | 7.2 | 0.37 | 7 — 8 | 50 | 7.3 | 0.34 | 5 — 8 |
| 9 | 24 | 7.2 | 0.43 | 7 — 8 | | | | | | | | | | | | |

TABLE 33

Radius and Carpals: Mean and Standard Deviation of Greatest Transverse Breadth of the Diaphysis and of the Epiphysis of the Radius, the Radial Index and the Number of Carpal Centers for the Cleveland Public School Children

| Age, Years | Radius, Diaphysis | | | Radius, Epiphysis | | | Radial Index | | | Number of Carpal Centers | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Children | Mean | S. D. | Children | Mean | S. D. | Children | Mean | S. D. |
| | | | | | | Boys | | | | | | |
| 5 | 9 | 20.6 | 0.83 | 9 | 16.3 | 1.89 | 9 | 79.3 | 7.72 | 9 | 4.6 | 1.64 |
| 6 | 40 | 21.3 | 1.46 | 40 | 17.8 | 1.68 | 40 | 83.8 | 6.78 | 40 | 5.2 | 1.35 |
| 7 | 40 | 22.1 | 1.28 | 40 | 19.7 | 1.89 | 40 | 89.3 | 6.49 | 40 | 6.3 | 0.96 |
| 8 | 44 | 22.8 | 1.67 | 44 | 21.4 | 1.86 | 44 | 94.0 | 4.24 | 44 | 6.8 | 0.61 |
| | | | | | | Girls | | | | | | |
| 5 | 9 | 18.8 | 1.13 | 9 | 16.8 | 1.87 | 9 | 89.1 | 7.01 | 9 | 7.0 | 0.00 |
| 6 | 31 | 19.5 | 1.07 | 31 | 17.5 | 1.60 | 31 | 89.3 | 6.72 | 31 | 6.6 | 0.70 |
| 7 | 32 | 20.7 | 1.45 | 32 | 19.2 | 2.13 | 32 | 92.9 | 7.31 | 32 | 6.9 | 0.50 |
| 8 | 30 | 21.6 | 1.96 | 30 | 21.5 | 1.95 | 30 | 99.3 | 4.81 | 30 | 7.0 | 0.00 |

epiphysis, and the number of epiphyses for metacarpals and phalanges present in the same individual are not altogether irrelevant is shown by the correlations of the radial epiphysis with the number of carpals and with the number of epiphyses which are given below. The coefficients are computed by the rank order method and corrected for corresponding values of r.

| Radial Epiphysis with: | Boys Children | Boys Correlation | Girls Children | Girls Correlation |
|---|---|---|---|---|
| | 2 Years | | | |
| Number of epiphyses for metacarpals and phalanges | 62 | +.49 | 47 | +.56 |
| Number of carpals | 62 | +.50 | 47 | +.21 |
| | 3 Years | | | |
| Number of epiphyses for metacarpals and phalanges | 103 | +.57 | | |
| Number of carpals | 103 | +.44 | | |

The radial epiphysis with the other epiphyses gives coefficients somewhat higher than is the relationship between the radial epiphysis and the number of carpal bones.

### THE FOOT

The process of ossification in the foot is more rapid than in the hand and the sex differences while present in the same traits are

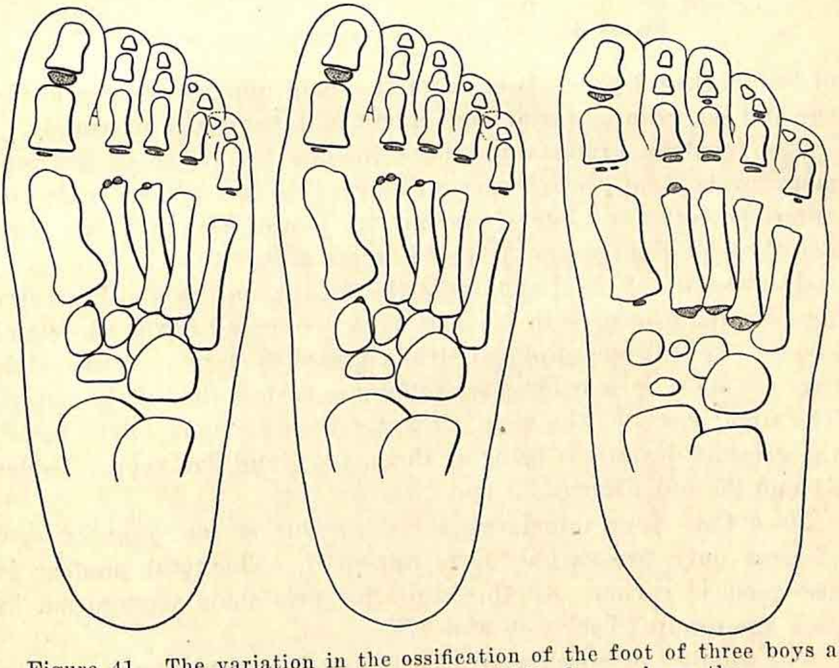


Figure 41. The variation in the ossification of the foot of three boys at exactly three years of age. The middle figure shows the average development for age and sex

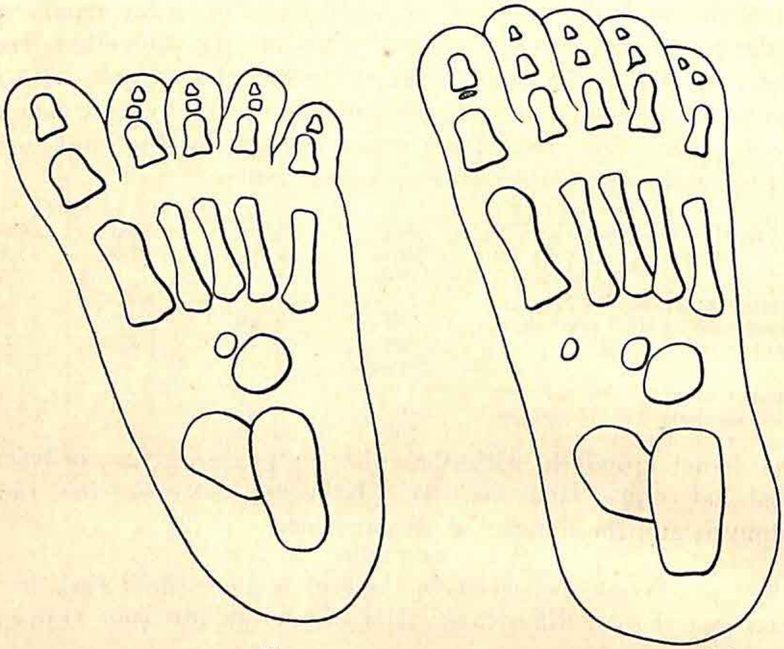


Figure 42. Average ossification at one year

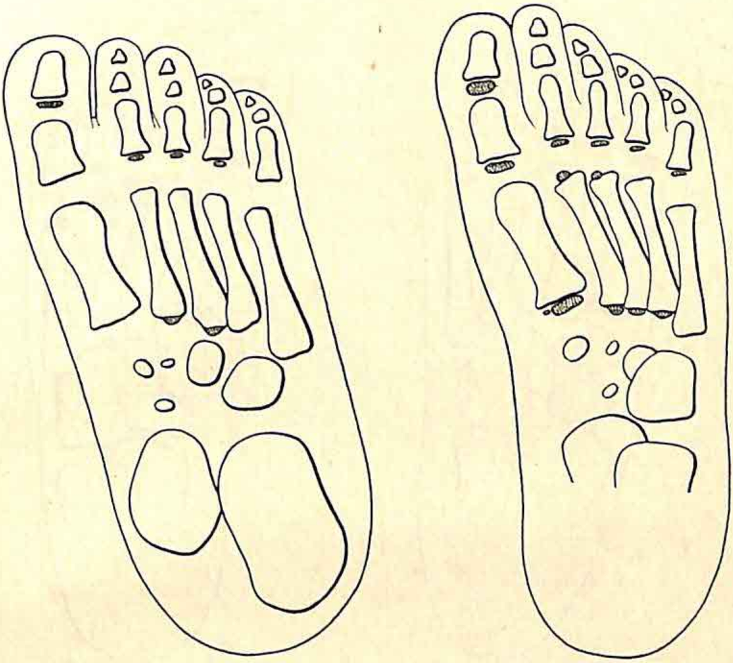
of less marked degree. Because of the small number of cases in the age and sex groups, variability cannot be interpreted accurately.

The roentgenograms reproduced include the range of development in boys at three years (Figure 41) and sixteen pairs of antero-posterior and lateral views of the foot of boys and girls from one through eight years of age (Figures 42 to 52).

The breadth of the diaphysis of the tibia is, on the whole, greater for boys than for girls in the New York group and in the Cleveland series. The distal epiphysis, while generally larger in the girls does not show as clear cut a sex difference as does that of the radius. The tibial index of the girls is greater than or equal to the boys', the greatest deviations being at three, four, and five years (Tables 34 and 35 and Figures 53 and 55).

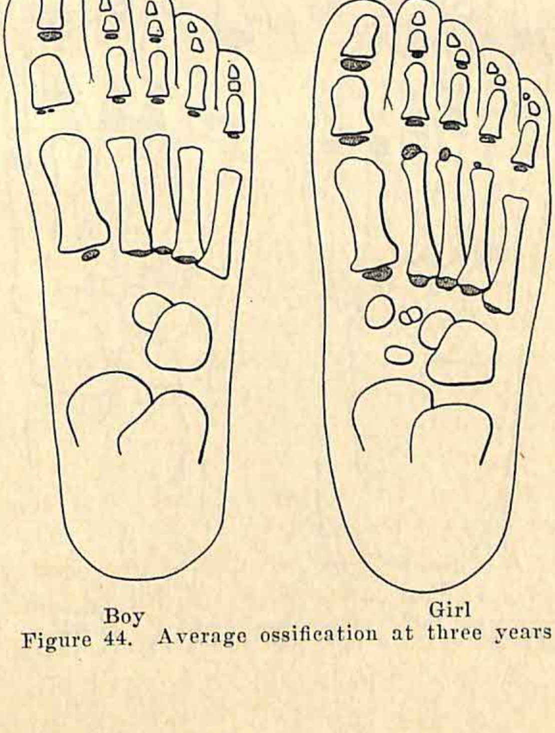
More than four tarsal bones are present at one year of age, whereas only two carpals have appeared. The total number is also reached earlier. In this trait the girls show acceleration in each age group (Tables 36 and 37).

The number of epiphyses for metatarsals and phalanges cannot be calculated in quite the same way as the corresponding epiphyses



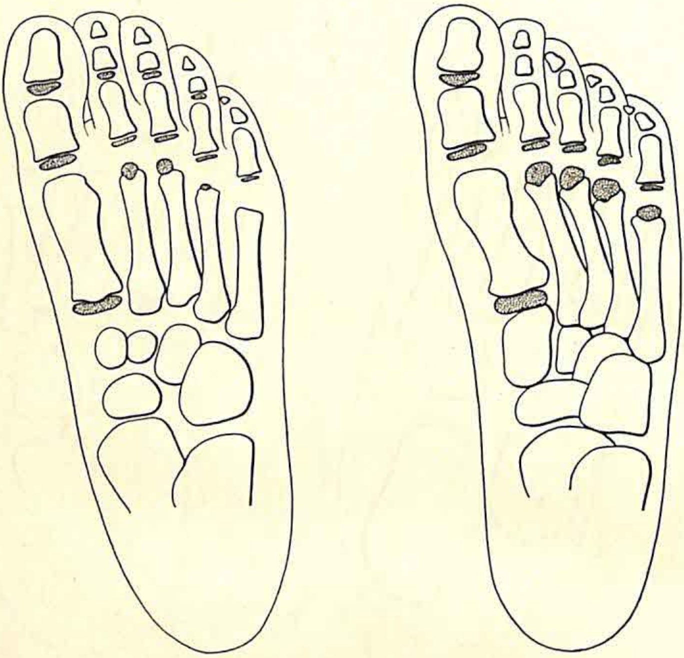
Boy Girl

Figure 43. Average ossification at two years



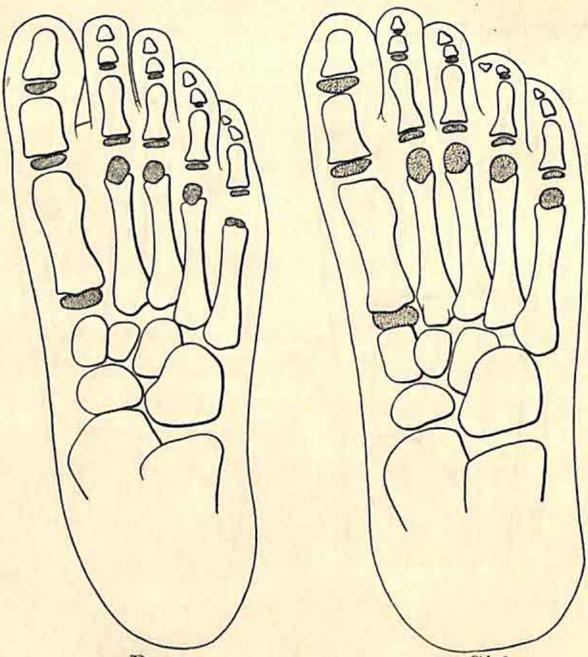
Boy Girl

Figure 44. Average ossification at three years



Boy Girl

Figure 45. Average ossification at four years



Boy Girl

Figure 46. Average ossification at five years

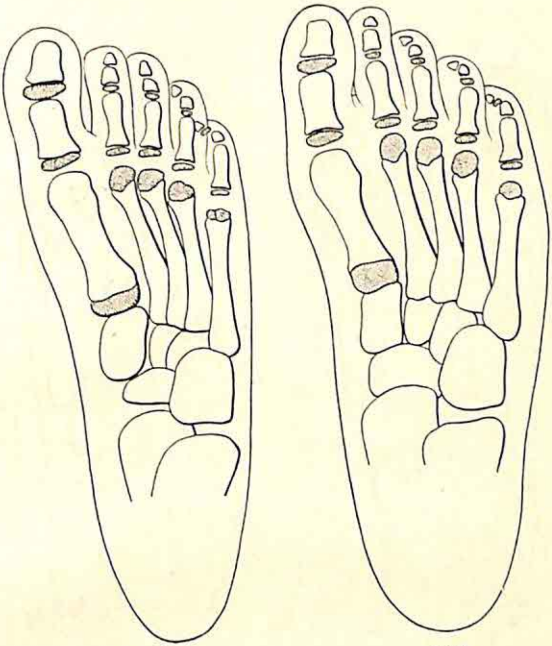


Figure 47. Average ossification at six years

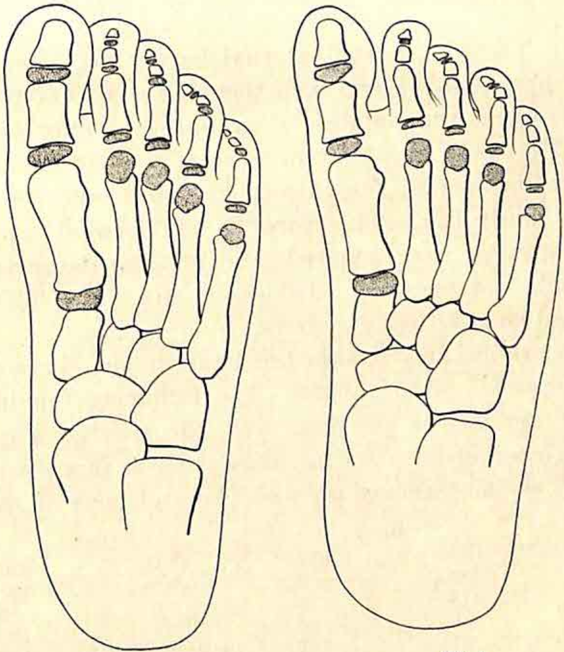


Figure 48. Average ossification at seven years

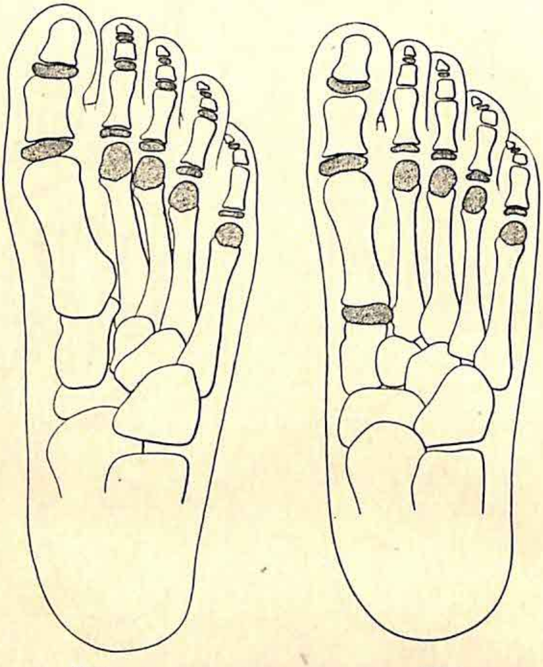
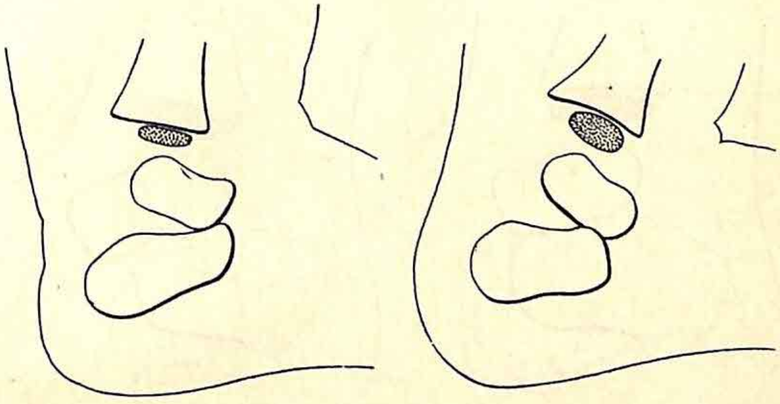


Figure 49. Average ossification at eight years

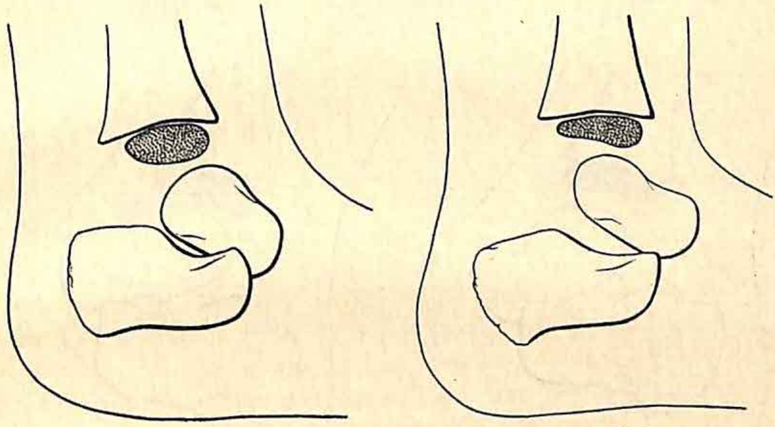
of the hand. The toes at the external border are often so curled that in the children over two who then have centers just appearing in that region, the number of epiphyses cannot be correctly estimated. Moreover, the final number is not constant as in the hand, for the degenerate fourth and fifth toes sometimes lack an epiphysis in adult life. Therefore, in children at one and two years, all epiphyses were counted, and afterwards only those for the metatarsals are recorded (Tables 36 and 37). The girls are much more advanced than the boys.

Early appearance and female acceleration are characteristic of the distal epiphysis of the fibula. The following tabulation indicates that at the end of the first year, the roentgenograms of 56 per cent of girls and 23 per cent of boys show this shadow and it is universally present among girls of two and boys of three years.

| | Boys | | Girls | |
|---|---|---|---|---|
| Age, Years | Children | Per cent | Children | Per cent |
| 1 | 13 | 23 | 9 | 56 |
| 2 | 15 | 93 | 11 | 100 |
| 3 | 21 | 100 | 21 | 100 |



Boy One year Girl



Boy Two years Girl

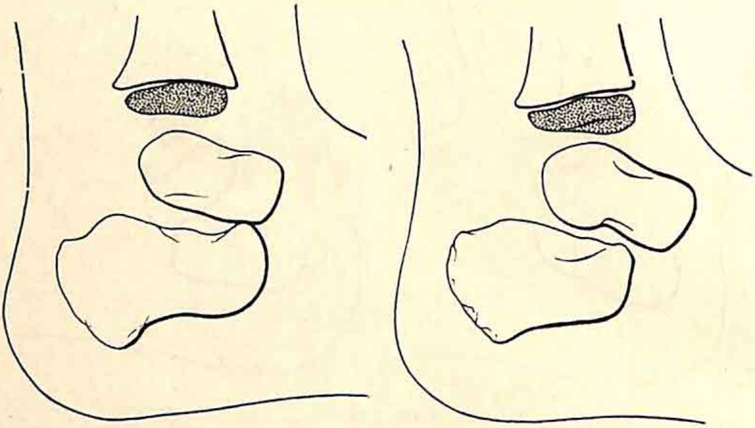
Figure 50

Because of its coincidence with the tibial epiphysis, the fibular was not outlined on the roentgenograms.

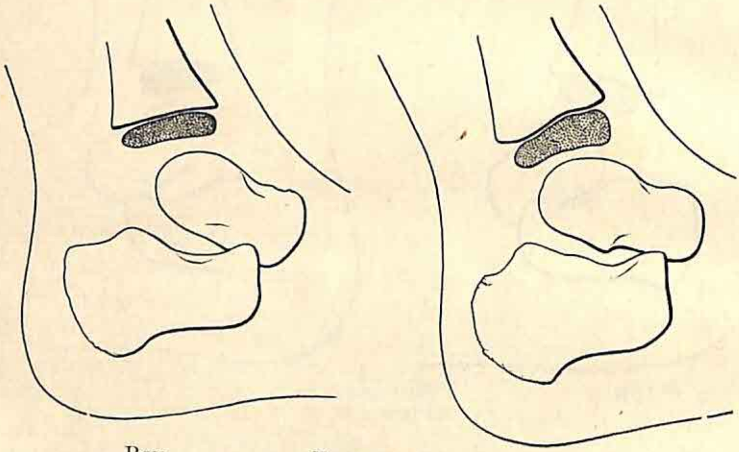
The size of the calcaneum as represented by the maximum shadow on the roentgenogram follows the procedures of increasing bone growth and of epiphysial ossification. That is, the averages of the New York series are higher for the boys at one and two years; then when the epiphysis begins to appear among the four-year-old girls, the female has the longer bone. The first appearance of the epiphysis takes place from two to three years earlier in girls (Tables 36, 37 and 38 and Figure 56).

### HAND IN RELATION TO FOOT

The outstanding differences between the ossification of hand and



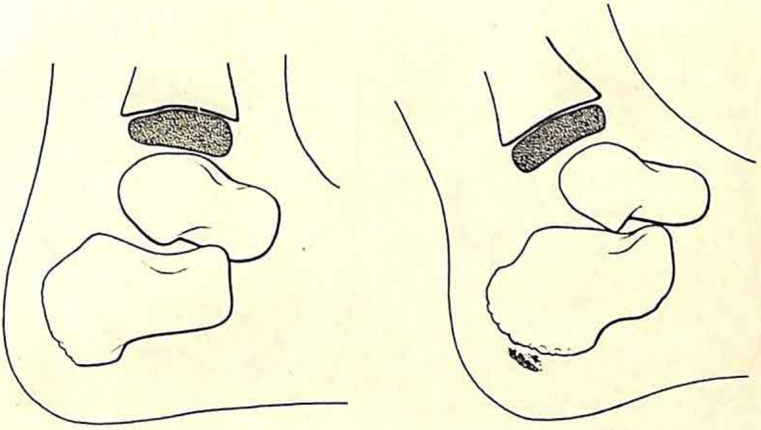
Boy Three years Girl



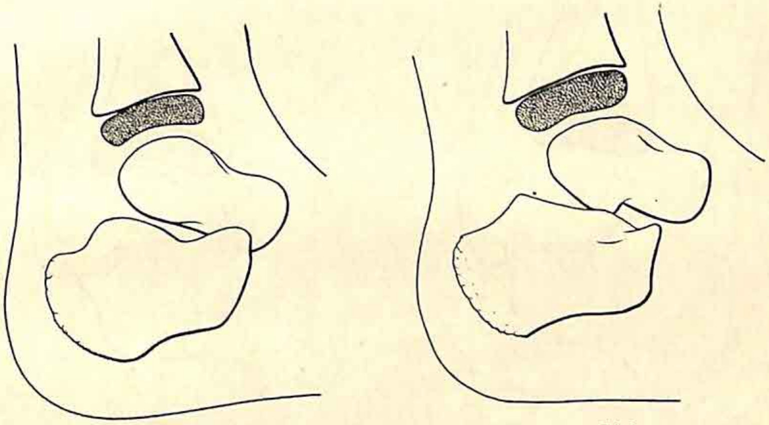
Boy Four years Girl

Figure 50—Continued

foot are the more rapid rate of the lower extremity and the tendency for a greater number of temporary irregularities in the process to appear there than in the hand. These anomalies are of two types, supernumerary centers for carpus and tarsus, and double epiphyses for metacarpals, metatarsals and phalanges, and proximal epiphyses for metacarpals and metatarsals. In the hand, the second type, proximal epiphyses where only distal are expected, is fairly common; the first is rare. The total number of all types of irregularity were distributed as follows among the New York children:



Boy Five years Girl

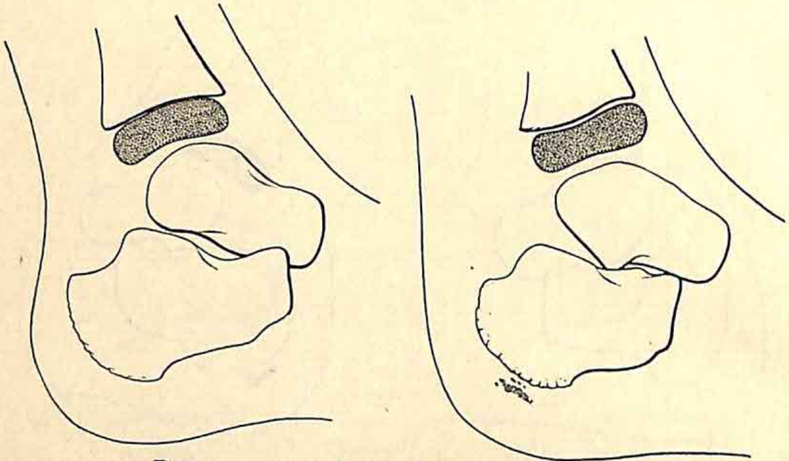


Boy Six years Girl

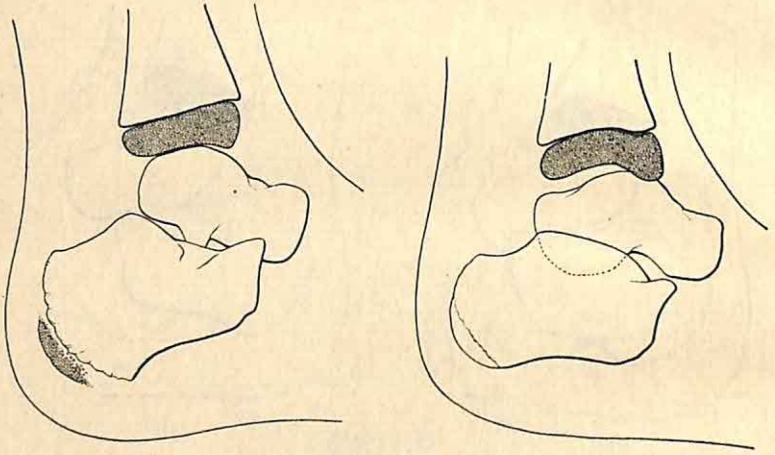
Figure 51

| | Individuals | Number with Irregularities | Per Cent Irregularities |
|---|---|---|---|
| | | Hand | |
| Boys | 98 | 18 | 18 |
| Girls | 62 | 7 | 10 |
| | | Foot | |
| Boys | 63 | 36 | 57 |
| Girls | 56 | 19 | 34 |

The three groups of private school children from New York, Detroit, and Iowa show proximal epiphyses for metacarpals and metatarsals in the frequencies listed below:



Boy Seven years Girl



Boy Eight years Girl

Figure 52

| | Boys | Per Cent | Girls | Per Cent |
|---|---|---|---|---|
| Metacarpals | 367 | 16.6 | 350 | 5.7 |
| Metatarsals | 86 | 24.4 | 91 | 6.6 |

In all groups the sex differences and percentages of incidence are so nearly uniform that only the combined figures are given. Both kinds of irregularity, although more common in the foot than in the hand, disappear there more quickly because of the more rapid rate of ossification. The incidence is higher in boys than in girls and union and disappearance is slower, in accord with the normal sex difference (44).

TABLE 34

Tibia: Mean, Standard Deviation and Range of Greatest Transverse Breadth of Diaphysis and Epiphysis of the Tibia, and the Tibial Index for the New York Private School Children

| Age, Years | Tibia, Diaphysis | | | | Tibia, Epiphysis | | | | Tibial Index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | | | Boys | | | | | | |
| 1 | 14 | 18.9 | 1.10 | 17 — 21 | 14 | 8.9 | 3.59 | 0 — 14 | 14 | 46.6 | 18.03 | 22 — 70 |
| 2 | 16 | 24.1 | 1.75 | 20 — 27 | 16 | 16.5 | 2.09 | 10 — 19 | 15 | 68.6 | 9.31 | 45 — 90 |
| 3 | 18 | 26.0 | 1.82 | 22 — 29 | 20 | 20.4 | 2.18 | 16 — 26 | 18 | 78.8 | 5.78 | 70 — 93 |
| 4 | 16 | 27.2 | 1.71 | 24 — 31 | 17 | 23.0 | 2.22 | 20 — 28 | 16 | 84.5 | 4.68 | 77 — 92 |
| 5 | 13 | 28.8 | 1.58 | 25 — 31 | 14 | 25.1 | 2.52 | 21 — 30 | 13 | 87.4 | 6.75 | 75 — 97 |
| 6 | 17 | 29.7 | 1.40 | 26 — 32 | 17 | 27.8 | 1.58 | 24 — 30 | 17 | 93.7 | 2.78 | 89 —100 |
| 7 | 12 | 31.8 | 1.53 | 29 — 34 | 12 | 30.2 | 1.91 | 27 — 33 | 12 | 95.0 | 2.45 | 88 —100 |
| 8 | 8 | 34.2 | 2.44 | 31 — 39 | 12 | 33.4 | 2.63 | 29 — 38 | 8 | 96.0 | 3.95 | 91 —103 |
| | | | | | | Girls | | | | | | |
| 1 | 9 | 19.2 | 1.47 | 18 — 22 | 9 | 10.9 | 1.66 | 8 — 13 | 9 | 56.4 | 6.02 | 47 — 68 |
| 2 | 11 | 22.6 | 0.88 | 21 — 24 | 11 | 15.9 | 1.68 | 14 — 18 | 11 | 70.3 | 5.85 | 61 — 82 |
| 3 | 21 | 24.8 | 1.30 | 22 — 28 | 21 | 21.1 | 2.25 | 17 — 24 | 21 | 85.2 | 6.31 | 71 — 96 |
| 4 | 20 | 27.2 | 1.63 | 25 — 31 | 21 | 24.4 | 2.19 | 21 — 29 | 20 | 90.2 | 3.90 | 85 — 96 |
| 5 | 12 | 28.3 | 1.37 | 26 — 30 | 15 | 26.4 | 1.99 | 22 — 29 | 12 | 92.0 | 3.56 | 85 — 97 |
| 6 | 11 | 30.6 | 1.67 | 27 — 33 | 13 | 28.2 | 2.42 | 23 — 32 | 11 | 93.7 | 4.00 | 85 —100 |
| 7 | 11 | 32.4 | 1.49 | 30 — 36 | 13 | 30.7 | 1.68 | 28 — 35 | 11 | 94.4 | 2.56 | 88 — 97 |
| 8 | 12 | 33.7 | 2.01 | 31 — 37 | 14 | 32.4 | 2.38 | 29 — 38 | 12 | 96.5 | 4.92 | 86 —103 |

TABLE 35

Tibia: Mean, Standard Deviation and Range of Greatest Transverse Breadth of Diaphysis and Epiphysis of the Tibia and the Tibial Index for the Cleveland Public School Children

| Age, Years | Tibia, Diaphysis |  |  |  | Tibia, Epiphysis |  |  |  | Tibial Index |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
|  |  |  |  |  |  | Boys |  |  |  |  |  |  |
| 5 | 10 | 29.5 | 2.20 | 25 — 33 | 10 | 27.5 | 1.63 | 25 — 30 | 10 | 93.5 | 5.45 | 88 —108 |
| 6 | 44 | 30.7 | 1.61 | 28 — 34 | 44 | 28.5 | 1.47 | 26 — 32 | 44 | 92.8 | 2.67 | 85 — 97 |
| 7 | 44 | 31.8 | 1.55 | 29 — 36 | 45 | 29.6 | 1.98 | 26 — 34 | 44 | 93.0 | 3.26 | 87 —100 |
| 8 | 57 | 33.2 | 2.06 | 26 — 38 | 59 | 31.4 | 2.02 | 27 — 36 | 57 | 94.1 | 3.85 | 88 —112 |
|  |  |  |  |  |  | Girls |  |  |  |  |  |  |
| 5 | 8 | 28.9 | 1.36 | 27 — 31 | 8 | 27.0 | 1.63 | 24 — 29 | 8 | 93.4 | 3.80 | 89 —100 |
| 6 | 36 | 29.4 | 1.92 | 26 — 34 | 36 | 27.8 | 2.19 | 24 — 33 | 36 | 94.3 | 4.77 | 87 —111 |
| 7 | 34 | 31.2 | 1.80 | 28 — 35 | 35 | 29.9 | 2.13 | 26 — 34 | 34 | 95.7 | 3.80 | 87 —103 |
| 8 | 38 | 32.9 | 2.39 | 27 — 38 | 38 | 32.1 | 2.73 | 26 — 39 | 38 | 97.4 | 2.79 | 93 —103 |

TABLE 36

Centers of Ossification of the Foot: Mean, Standard Deviation and Range in Number of Tarsal Centers, Number of Epiphyses for Metatarsals and Phalanges and Per Cent of Appearance of Epiphysis of Calcaneum for the New York Private School Children

| Age, Years | Number of Tarsal Centers | | | | Number of Epiphyses for Metatarsals and Phalanges | | | | Number of Epiphyses for Metatarsals | | | | Presence of Calcaneum Epiphysis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range | Children | Per cent |
| | | | | | | | Boys | | | | | | | |
| 1 | 15 | 4.3 | 0.70 | 4 — 6 | 15 | 0.3 | 0.60 | 0 — 2 | | | | | 15 | 00 |
| 2 | 16 | 5.5 | 1.37 | 4 — 7 | 16 | 4.2 | 3.26 | 0 — 9 | | | | | 16 | 00 |
| 3 | 21 | 6.4 | 1.13 | 4 — 7 | | | | | 21 | 1.4 | 1.05 | 0 — 3 | 21 | 00 |
| 4 | 18 | 6.4 | 1.06 | 4 — 7 | | | | | 18 | 2.8 | 1.77 | 0 — 5 | 18 | 00 |
| 5 | 15 | 7.0 | 0.00 | 7 — 7 | | | | | 13 | 4.4 | 1.00 | 2 — 5 | 13 | 00 |
| 6 | | | | | | | | | 17 | 5.0 | 0.00 | 5 — 5 | 17 | 00 |
| 7 | | | | | | | | | | | | | 16 | 00 |
| 8 | | | | | | | | | | | | | 14 | 43 |
| 9 | | | | | | | | | | | | | 9 | 89 |
| | | | | | | | Girls | | | | | | | |
| 1 | 9 | 4.6 | 0.96 | 4 — 7 | 9 | 3.8 | 3.77 | 0 — 9 | | | | | 9 | 00 |
| 2 | 11 | 6.0 | 1.04 | 4 — 7 | 10 | 8.8 | 3.15 | 1 —13 | | | | | 11 | 00 |
| 3 | 21 | 6.9 | 0.47 | 5 — 7 | | | | | 20 | 3.9 | 1.07 | 2 — 5 | 21 | 00 |
| 4 | 22 | 7.0 | 0.00 | 7 — 7 | | | | | 21 | 4.8 | 0.66 | 2 — 5 | 22 | 4 |
| 5 | | | | | | | | | 13 | 5.0 | 0.00 | 5 — 5 | 15 | 27 |
| 6 | | | | | | | | | | | | | 13 | 46 |
| 7 | | | | | | | | | | | | | 17 | 82 |
| 8 | | | | | | | | | | | | | 15 | 100 |

TABLE 37

Centers of Ossification of the Foot: Per Cent of Appearance of Epiphysis of Calcaneum, Mean and Standard Deviation of the Number of Epiphyses of the Metatarsals and the Number of Tarsal Centers for the Cleveland Public School Children

| Age, Years | Presence of Calcaneum Epiphysis | | Number of Epiphyses for Metatarsals | | | Number of Tarsal Centers | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Per cent | Children | Mean | S. D. | Children | Mean | S. D. |
| | | | | Boys | | | | |
| 5 | 10 | 00 | 10 | 4.8 | 0.40 | 10 | 6.9 | 0.30 |
| 6 | 44 | 00 | 44 | 4.9 | 0.28 | 44 | 7.0 | 0.14 |
| 7 | 45 | 13 | 45 | 5.0 | 0.16 | 45 | 7.0 | 0.00 |
| 8 | 59 | 37 | | | | | | |
| | | | | Girls | | | | |
| 5 | 8 | 25 | 8 | 5.0 | 0.00 | 8 | 7.0 | 0.00 |
| 6 | 36 | 44 | 36 | 5.0 | 0.00 | 36 | 7.0 | 0.00 |
| 7 | 35 | 86 | 34 | 5.0 | 0.00 | 35 | 7.0 | 0.00 |
| 8 | 39 | 100 | 38 | 5.0 | 0.00 | 38 | 7.0 | 0.00 |

TABLE 38

Calcaneum: Mean, Standard Deviation and Range in Millimeters for the New York Private School and Cleveland Public School Children

| Age, Years | New York Private School | | | | Cleveland Public Schools | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | Mean | S. D. | Range | Children | Mean | S. D. | Range |
| | | | | Boys | | | | |
| 1 | 15 | 27.3 | 2.30 | 23 — 32 | | | | |
| 2 | 18 | 34.5 | 2.24 | 29 — 39 | | | | |
| 3 | 21 | 39.5 | 2.92 | 34 — 46 | | | | |
| 4 | 18 | 42.3 | 3.87 | 35 — 47 | | | | |
| 5 | 15 | 49.1 | 4.14 | 38 — 55 | 10 | 49.4 | 3.23 | 46 — 56 |
| 6 | 17 | 51.8 | 3.57 | 44 — 59 | 44 | 50.2 | 3.37 | 43 — 57 |
| 7 | 16 | 56.4 | 2.52 | 52 — 61 | 45 | 53.8 | 4.25 | 44 — 62 |
| 8 | 14 | 62.5 | 6.02 | 56 — 78 | 59 | 58.4 | 5.60 | 44 — 74 |
| | | | | Girls | | | | |
| 1 | 9 | 26.1 | 2.94 | 21 — 31 | | | | |
| 2 | 11 | 32.3 | 2.26 | 29 — 37 | | | | |
| 3 | 21 | 39.7 | 2.23 | 36 — 44 | | | | |
| 4 | 22 | 45.5 | 4.27 | 38 — 53 | | | | |
| 5 | 15 | 51.7 | 3.19 | 43 — 58 | 8 | 48.2 | 4.35 | 40 — 54 |
| 6 | 13 | 54.7 | 4.06 | 48 — 61 | 36 | 50.9 | 4.72 | 43 — 62 |
| 7 | 17 | 59.1 | 3.46 | 49 — 64 | 35 | 57.0 | 5.80 | 43 — 67 |
| 8 | 15 | 65.3 | 3.17 | 61 — 72 | 39 | 62.6 | 5.45 | 49 — 74 |

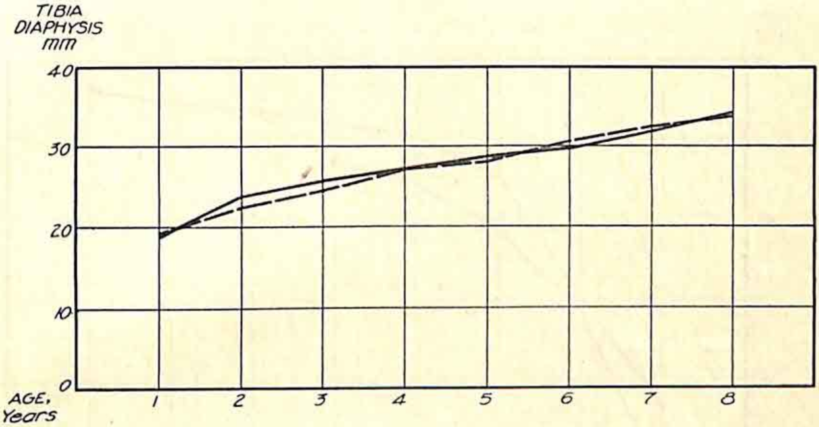


Figure 53. Diaphysis of the tibia, maximum transverse diameter at distal extremity. New York Private School Children. Boys (———), Girls (- - - -)

There is a suggestion of the possible effect of function in the prevalence of irregularities in the extremity on which the greater strain is put in early childhood. Another very slender straw blowing in that direction is the contrasted degrees of development of the hand and foot seen in the roentgenograms of an infant nursing gorilla generously put at the writer's disposal by Dr. Noback. The hand, in this case the implement more in use, parallels that of a human girl from eighteen to twenty-three months plus an ulnar epiphysis two or three years ahead of its time, while the foot is less mature than that of a girl at twelve months.

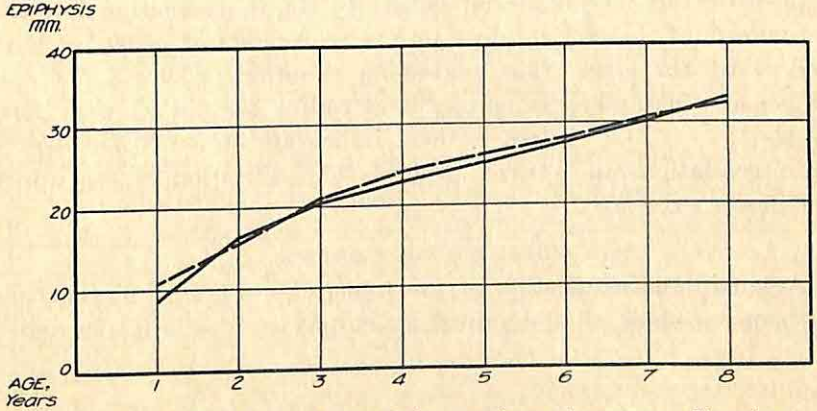


Figure 54. Epiphysis of the tibia, maximum transverse diameter. New York Private School Children. Boys (———), Girls (- - - -)

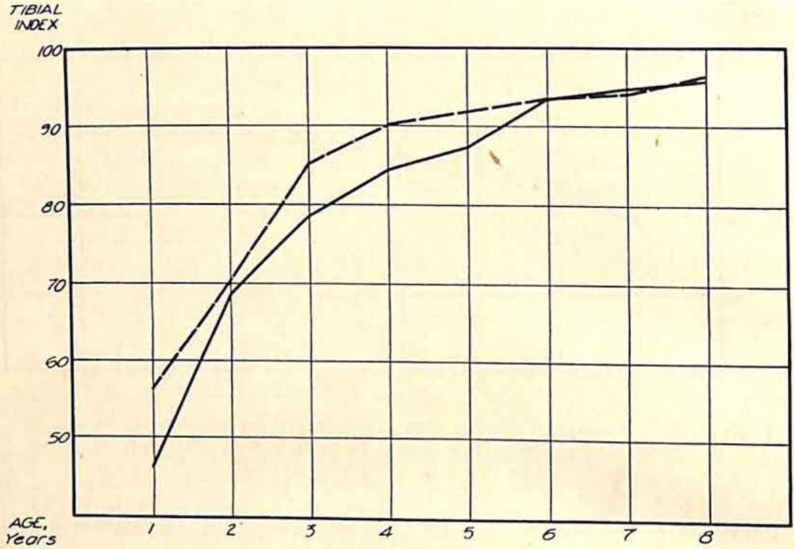


Figure 55. Tibial Index for the New York Private School Children. Boys (———), Girls (- - - -)

The similarity of the foot to the hand in the New York group appears in the trend of sex differences, the broader tibial and radial shafts of the boys, the larger epiphyses and greater number of tarsal and carpal centers of the girls. There is also a tendency, brought out by the coefficient of correlation, for the ossification of both extremities to be interdependent (Table 39). The maturity ratings as measured by the tibial and radial indices show a positive, but irregular and generally slight association but the actual size of the two epiphyses gives coefficients of +.60 for boys and +.64 for girls. The regression equations where y = epiphysis of tibia and x = epiphysis of radius are (boys) y = .65x, (girls) y = .83x. There is then, indication of a marked degree of interrelationship between progress of ossification in the upper and lower extremity.

### HEAD OF THE HUMERUS

Again in the ossification of the humeral head we find the boys with more robust shafts topped by epiphyses less fully developed

TABLE 39
Correlations between the Ossification of the Tibia and the Radius of New York Private School Children

| Age, Years | Children | Correlation | Children | Correlation |
|---|---|---|---|---|
| | Indices | | | |
| | Boys | | Girls | |
| 2 | 14 | +.80 | 11 | +.64 |
| 3 | 18 | +.30 | 21 | +.59 |
| 4 | 16 | +.17 | 20 | +.52 |
| 5 | 12 | +.16 | 12 | +.30 |
| 6 | 17 | +.16 | 11 | +.16 |
| 7 | 12 | +.36 | 12 | +.80 |
| 8 | 8 | +.25 | 12 | +.68 |
| All Groups | 97 | +.31 | 98 | +.53 |
| | Distal Epiphyses | | | |
| 2 | 15 | +.80 | 11 | +.60 |
| 3 | 20 | +.57 | 21 | +.69 |
| 4 | 17 | +.62 | 21 | +.56 |
| 5 | 13 | +.47 | 15 | +.82 |
| 6 | 17 | +.34 | 13 | +.54 |
| 7 | 12 | +.65 | 13 | +.57 |
| 8 | 12 | +.81 | 14 | +.72 |
| All Groups | 106 | +.60 | 108 | +.64 |

than the girls. The sex difference in diaphysial breadth is shown below:

| Age, Years | Middle Diameter | | Breadth below Head | |
|---|---|---|---|---|
| | Boys | Girls | Boys | Girls |
| 2 | 13.0 | 12.0 | 26.3 | 26.0 |
| 3 | 14.4 | 13.5 | 29.6 | 27.7 |
| 4 | 14.8 | 14.2 | 30.6 | 29.3 |

There are two proximal epiphyses for the humerus, an inner for the head and an outer for the tuberosity. Cohn (18) in his atlas of normal bones and joints stated on the basis of his data that "roentgenologically there is only one definite epiphysis." The two-year-old group of boys, the youngest radiographed from the City and Country School, is equally divided between those advanced as far as one center and those with two definitely separated. All the girls at two, the boys at three, and retarded boys as late as five years of age show separate, clear-cut epiphyses (Figure 58 and 59).

From one to six years of age, it was possible to trace the development of the humeral head. Later, when distinctions were finer and the individual muscular development obscured age changes, the lack of absolute uniformity in the position on a roentgenogram made primarily for the chest stopped the study. The stages from two to six years are shown in the five diagrams. There is no more than a six-month difference between the average condition of boys and girls for each year. The boys, however, show a greater variety of acceleration and retardation within the groups. Fewer subgroups in a year range had to be made for the girls.

Age is a prominent factor in the ossification of the humerus within a year's range. The average age in months of the groups sorted according to maturity of ossification at each year from two through six decreases almost uniformly from the most complete to the most rudimentary stage (Table 40). Group I is the most mature, group IV the least. The connection seems closer than exists between age and ossification of the hand. An equally harmonious relationship seems to be established with ossification at the distal end of the upper extremity. The average radial index, as shown (page 125), for each stage of ossification of the humeral head decreases as regularly with lesser maturity of the humeral head as does the average age in months on Table 40.

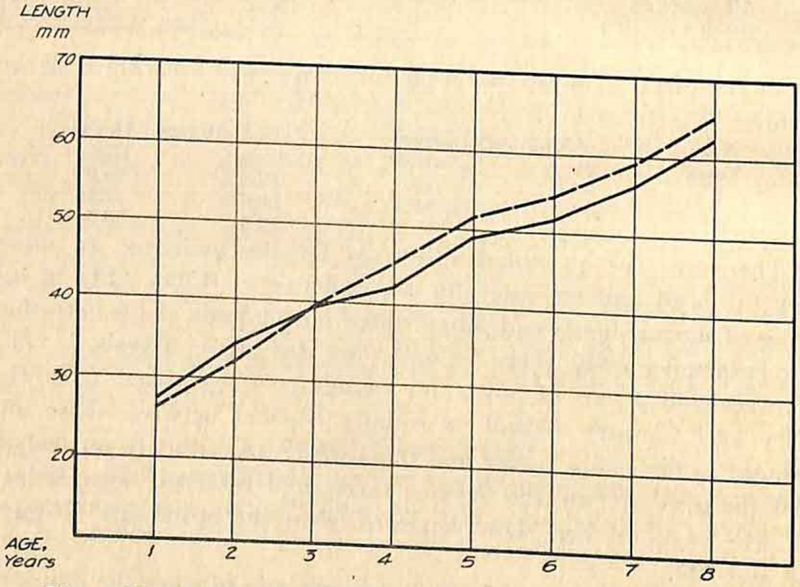
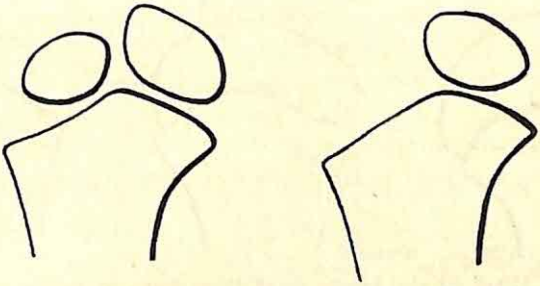


Figure 56. Calcaneum of the New York Private School Children. Boys (———), Girls (- - - -)



Girl 2 years

Boy 3 years

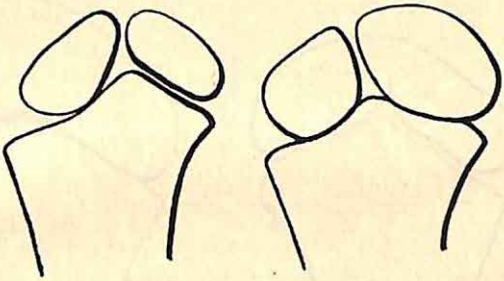


Figure 57. Ossification of the proximal end of the humerus. Boys at two years

| Age, Years | Group I | Group II | Group III | Group IV |
|---|---|---|---|---|
| | | Boys | | |
| 2 | 42 | 40 | | |
| 3 | 66 | 65 | 34 | |
| 4 | 77 | 67 | | |
| 5 | 84 | 82 | 79 | 58 |
| 6 | 85 | 88 | 79 | 70 |
| | | Girls | | |
| 2 | 63 | 61 | | |
| 3 | 75 | 72 | 64 | |
| 4 | 82 | 76 | | |
| 5 | 87 | 84 | 77 | |
| 6 | 89 | 90 | 78 | |

### OSSIFICATION AND STATURE

The stage of ossification reached at a given time has shown a certain interrelationship in each joint just considered, and the process of ossification is not isolated from the growth of the rest of the body. The dependence of the breadth of long bones and the rate of their epiphysial development on total body length, is only slightly less close than that of trunk length (Tables 16 and 41). Correlations for stature and breadth of the radial diaphysis are remarkably regular for the boys' age groups and only a little

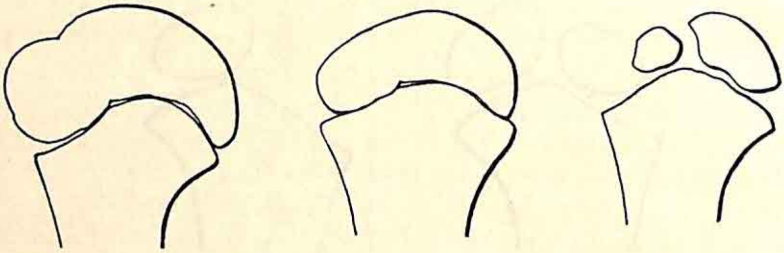


Figure 58. Head of the humerus of three boys at five years of age

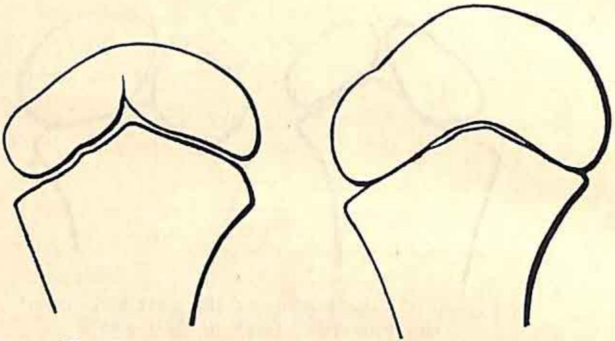


Figure 59. Boy 6 years Boy four years

TABLE 40
Head of the Humerus: Mean Age in Months for Groups of Decreasing Maturity of Ossification

| Age, Years | Children | Group I Mean Age, Months | Group II Mean Age, Months | Group III Mean Age, Months | Group IV Mean Age, Months |
|---|---|---|---|---|---|
| | | | Boys | | |
| 2 | 10 | 24.2 | 23.8 | | |
| 3 | 21 | 40.0 | 35.7 | 33.7 | 32.3 |
| 4 | 25 | 49.3 | 46.5 | 47.0 | 44.4 |
| 5 | 20 | 59.7 | 58.7 | 57.9 | 56.7 |
| 6 | 24 | 71.0 | 71.0 | 71.5 | 72.7 |
| | | | Girls | | |
| 2 | 8 | 27.8 | 26.0 | | |
| 3 | 17 | 39.6 | 40.0 | 35.8 | |
| 4 | 22 | 48.7 | 46.0 | | |
| 5 | 27 | 60.6 | 58.7 | 59.1 | |
| 6 | 25 | 71.6 | 72.7 | 68.0 | |

TABLE 41

Correlations Between Stature and Radial Diaphysis, Radial Epiphysis, and Radial Index for the New York Private School and the Merrill-Palmer Nursery School Children

| Age, Years | Stature and Diaphysis | | Stature and Epiphysis | | Stature and Index | |
|---|---|---|---|---|---|---|
| | Children | Correlation | Children | Correlation | Children | Correlation |
| | | | Boys | | | |
| 1 | | | | | 10 | +.48 |
| 2 | 36 | +.49 | 36 | +.37 | 36 | +.22 |
| 3 | 71 | +.57 | 71 | +.50 | 75 | +.41 |
| 4 | 83 | +.50 | 83 | +.23 | 86 | +.27 |
| 5 | 79 | +.60 | 79 | +.41 | 77 | +.18 |
| 6 | 33 | +.63 | 33 | +.58 | 36 | +.32 |
| 7 | 23 | +.50 | 23 | +.58 | 23 | +.34 |
| 8 | 18 | +.60 | 18 | +.84 | 18 | +.05 |
| All Groups | 343 | +.57 | 343 | +.43 | 361 | +.28 |
| | | | Girls | | | |
| 1 | | | | | 10 | +.57 |
| 2 | 29 | +.53 | 29 | +.70 | 30 | +.47 |
| 3 | 79 | +.22 | 79 | +.44 | 78 | +.32 |
| 4 | 91 | +.61 | 91 | +.52 | 91 | +.25 |
| 5 | 77 | +.39 | 77 | +.37 | 77 | +.10 |
| 6 | 37 | +.37 | 37 | +.14 | 37 | +.21 |
| 7 | 23 | +.41 | 23 | +.51 | 23 | +.19 |
| 8 | 15 | +.57 | 15 | +.47 | 15 | +.03 |
| All Groups | 351 | +.43 | 351 | +.44 | 361 | +.20 |

less so among the girls; those for stature and radial epiphysis have a wider range for both sexes but all are positive. The weighted and averaged coefficients of correlation are +.57 and +.43 for diaphysis, +.43 and +.44 for epiphysis.

Because of the small number of cases in each age group of the foot, only one correlation was tried between a trait and stature. This was for a group of sixteen boys at three years. The coefficient of tibial diaphysis and stature was +.50, radial diaphysis and stature for the same individuals being +.63.

The entire carpal area, measured and correlated in the Baldwin, Busby, and Garside (5) study, bears the same relationship to stature as does the transverse diameter of the single radial epiphysis, +.42 and +.58. The coefficients when the anatomic index is substituted, shrink to +.25 and +.42 just as the coefficients for stature and radial index are +.28 and +.20, considerably lower

| | Stature and Carpal Area* | | Stature and Anatomic Index* | |
|---|---|---|---|---|
| Age, Years | Children | Correlation | Children | Correlation |
| | | Boys | | |
| 2 | 13 | +.41 | | |
| 3 | 20 | +.62 | 20 | +.46 |
| 4 | 25 | +.29 | 24 | +.11 |
| 5 | 28 | +.64 | 28 | +.53 |
| 6 | 40 | +.39 | 39 | +.24 |
| 7 | 44 | +.29 | 44 | +.11 |
| 8 | 47 | +.41 | 46 | +.20 |
| All Groups | 217 | +.42 | 201 | +.25 |
| | | Girls | | |
| 2 | 13 | +.17 | | |
| 3 | 25 | +.69 | 24 | +.53 |
| 4 | 31 | +.47 | 31 | +.29 |
| 5 | 38 | +.50 | 38 | +.31 |
| 6 | 40 | +.65 | 40 | +.51 |
| 7 | 36 | +.70 | 36 | +.40 |
| 8 | 30 | +.61 | 30 | +.54 |
| All Groups | 213 | +.58 | 199 | +.42 |

*Adapted from Baldwin, Bird T., Busby, Laura M., and Garside, Helen V.: Anatomic Growth of Children: A Study of Some Bones of the Hand, Wrist, and Lower Forearm by Means of Roentgenograms. Univ. Iowa Stud., Stud. in Child Welfare, 1928, 4, No. 1, Pp. 88. (p. 50 and 62).

than the coefficients obtained from its component diameters. This destruction of relationship by correlating indices instead of measurements has been already noted for the tibial and radial epiphyses (Table 39).

Ossification, at least as it takes place in the hand, furnishes further evidence that the body tends to develop as a whole between the ages of two and eight.

# CHAPTER IV

## DENTITION

The knowledge of the dental development of the City and Country School children is uneven in amount and quality. The records are for three age periods and from three sources. From the registrar's information blank is the mother's statement, verified whenever possible by the baby book, of the date on which the first tooth erupted. The average time has been calculated for 277 children and is given for what it is worth. For the closing period of the first dentition, there are records of the Nursery School children made every two months by the anthropologist and for the beginning of the second dentition, examinations were taken by the same person in the same time intervals of the children from five through eight years of age. These records cover a period of three years. The third source of material was the most extensive. At the annual physical examination by the school's pediatrician the number of deciduous and permanent teeth was set down, the records covering a period of ten years. There are several sources of error in the data. All dental examinations were made by a physician but there were four individuals involved from 1919 to 1928. The findings were read to a similar variety of nurses who checked them on a rather confusing diagram. Since the child's teeth were not counted again for a year, there was no chance to check the inevitable mistakes. However, since most of the age groups are of fair size, the material is presented as close approximation to the truth.

### DECIDUOUS DENTITION

The age at which mothers said positively that the first tooth appeared averaged 7.6 months for 147 boys and for 130 girls. The standard deviations were also the same, 2.32 and 2.36 and the ranges of first appearance ran from three to fifteen months for boys and three to sixteen months for girls.

The following figures concerning the completion of the deciduous dentition were obtained for boys and girls from twenty-two to twenty-seven months:

| | Per Cent | | Mean | |
|---|---|---|---|---|
| | 20 Teeth | 16 Teeth | Number | S. D. |
| 16 Boys | 25 | 56 | 17.1 | 1.75 |
| 15 Girls | 33 | 40 | 16.7 | 2.98 |

These data show none of the sex differences characteristic of the time of eruption of permanent teeth. Professor Boas (12) has concluded that "only in the second deciduous molar, the one latest to erupt, do we find a consistent delay for the boys as compared to the girls."

### PERMANENT DENTITION

The percentage of cases in which each pair of permanent teeth was erupted in the age and sex groups from five to thirteen years are presented on Table 42. With the exception of the premolars, lower teeth almost uniformly precede upper teeth in date of appearance. All teeth broken through the gums are counted as present without distinction for degree of emergence. The carefully tested study of Psyche Cattell (17) arrived at the conclusions that finer divisions than whole teeth complicated the procedure without clarifying the results.

At the time of first eruption of each tooth and for the years immediately following, the girls lead the boys. The incisors and first molars are 100 per cent present for girls in age groups preceding the boys from one to two years. With the teeth appearing later, however, the boys begin to catch up. For canines and premolars, they equal or very slightly surpass the girls, not, however, until the age of thirteen.

### RELATION OF FIRST AND SECOND DENTITION

An urge to find out the relationship between the eruption of the first and second dentition has led to the following paper game which is offered with the idea that other investigators with adequate material may present it to the waiting world. For forty-nine children, there was a record of the appearance of the first deciduous tooth and of the permanent dentition at six or seven years of age. Ranking the first tooth as retarded or accelerated if it arrived at four or eleven months (plus or minus one standard deviation) and the state of the second dentition in terms of the percentages for each tooth in Table 42, led to these figures for the forty-nine cases:

Same rating for first and second dentition

| | |
|---|---|
| Average | 11 |
| Accelerated | 5 |
| Retarded | 10 |
| | 26 = 53% |

Second Dentition Superior to First

| First Second | |
|---|---|
| Average—Accelerated | 10 |
| Retarded—Average | 5 |
| Retarded—Accelerated | 2 |
| | 17 = 35% |

## TABLE 42

Permanent Teeth: Percentage of Children in which Each Pair was Erupted in the City and Country School Group of Children

| Age, Years | Permanent Incisors | | | | | | Permanent Molars | | | | | | Premolars | | | | | | Permanent Canines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | | | Lateral | | | First | | | Second | | | Posterior | | | Anterior | | | | | |
| | Children | Lower | Upper | Children | Lower | Upper | Children | Lower | Upper | Children | Lower | Upper | Children | Lower | Upper | Children | Lower | Upper | Children | Lower | Upper |
| | | | | | | | | | | Boys | | | | | | | | | | | |
| 5 | 71 | 4.2 | 0.0 | 71 | 0.0 | 0.0 | 71 | 0.0 | 0.0 | 71 | 0.0 | 0.0 | 71 | 0.0 | 0.0 | 71 | 0.0 | 0.0 | 71 | 0.0 | 0.0 |
| 6 | 76 | 34.2 | 6.5 | 76 | 6.6 | 0.0 | 76 | 31.6 | 26.3 | 76 | 0.0 | 0.0 | 76 | 0.0 | 0.0 | 76 | 0.0 | 0.0 | 76 | 0.0 | 0.0 |
| 7 | 76 | 85.5 | 40.0 | 76 | 26.3 | 10.5 | 76 | 80.3 | 72.4 | 76 | 0.0 | 0.0 | 76 | 1.3 | 1.3 | 76 | 0.0 | 0.0 | 76 | 1.3 | 0.0 |
| 8 | 64 | 95.3 | 85.9 | 64 | 67.2 | 35.9 | 64 | 90.6 | 95.3 | 64 | 0.0 | 0.0 | 64 | 3.1 | 4.7 | 64 | 1.6 | 3.1 | 64 | 4.7 | 0.0 |
| 9 | 65 | 98.5 | 93.8 | 65 | 89.2 | 63.1 | 65 | 95.4 | 96.9 | 65 | 0.0 | 0.0 | 65 | 1.5 | 1.5 | 65 | 3.1 | 9.2 | 65 | 15.4 | 7.7 |
| 10 | 46 | 100.0 | 97.8 | 46 | 97.8 | 84.8 | 46 | 100.0 | 100.0 | 46 | 2.2 | 0.0 | 46 | 10.9 | 13.0 | 46 | 17.4 | 19.6 | 46 | 32.6 | 23.9 |
| 11 | 39 | 100.0 | 100.0 | 39 | 100.0 | 97.4 | 39 | 100.0 | 100.0 | 39 | 7.7 | 2.6 | 39 | 30.8 | 38.5 | 39 | 43.6 | 56.4 | 39 | 71.8 | 51.3 |
| 12 | 35 | 100.0 | 100.0 | 35 | 100.0 | 97.1 | 35 | 100.0 | 100.0 | 35 | 40.0 | 25.7 | 35 | 62.9 | 68.6 | 35 | 71.4 | 77.1 | 35 | 82.9 | 65.7 |
| 13 | 21 | 100.0 | 100.0 | 21 | 100.0 | 100.0 | 21 | 100.0 | 100.0 | 21 | 76.2 | 52.4 | 21 | 85.7 | 90.5 | 21 | 100.0 | 100.0 | 21 | 100.0 | 85.7 |
| | | | | | | | | | | Girls | | | | | | | | | | | |
| 5 | 70 | 0.0 | 0.0 | 70 | 0.0 | 0.0 | 70 | 1.4 | 1.4 | 70 | 0.0 | 0.0 | 70 | 0.0 | 0.0 | 70 | 0.0 | 0.0 | 70 | 0.0 | 0.0 |
| 6 | 76 | 57.9 | 14.5 | 76 | 10.5 | 0.0 | 76 | 36.8 | 36.8 | 76 | 0.0 | 0.0 | 76 | 0.0 | 0.0 | 76 | 0.0 | 0.0 | 76 | 0.0 | 0.0 |
| 7 | 69 | 88.4 | 46.4 | 69 | 37.7 | 10.1 | 69 | 85.5 | 79.7 | 69 | 0.0 | 0.0 | 69 | 2.9 | 1.4 | 69 | 1.4 | 0.0 | 69 | 2.9 | 0.0 |
| 8 | 64 | 100.0 | 93.8 | 64 | 90.6 | 50.0 | 64 | 96.9 | 95.3 | 64 | 0.0 | 0.0 | 64 | 3.1 | 3.1 | 64 | 1.6 | 0.0 | 64 | 4.7 | 0.0 |
| 9 | 52 | 100.0 | 100.0 | 52 | 98.1 | 84.6 | 52 | 100.0 | 100.0 | 52 | 0.0 | 0.0 | 52 | 18.9 | 5.8 | 52 | 11.5 | 19.2 | 52 | 28.9 | 11.5 |
| 10 | 53 | 100.0 | 100.0 | 53 | 100.0 | 90.6 | 53 | 100.0 | 100.0 | 53 | 11.3 | 0.0 | 53 | 56.9 | 22.7 | 53 | 37.8 | 34.0 | 53 | 60.4 | 45.3 |
| 11 | 51 | 100.0 | 100.0 | 51 | 100.0 | 100.0 | 51 | 100.0 | 100.0 | 51 | 25.5 | 13.7 | 51 | 56.9 | 56.9 | 51 | 62.8 | 68.6 | 51 | 92.2 | 64.7 |
| 12 | 44 | 100.0 | 100.0 | 44 | 100.0 | 100.0 | 44 | 100.0 | 100.0 | 44 | 59.1 | 40.9 | 44 | 72.7 | 75.0 | 44 | 84.1 | 88.6 | 44 | 95.4 | 84.1 |
| 13 | 25 | 100.0 | 100.0 | 25 | 100.0 | 100.0 | 25 | 100.0 | 100.0 | 25 | 84.0 | 60.0 | 25 | 88.0 | 88.0 | 25 | 100.0 | 96.0 | 25 | 96.0 | 96.0 |

First Dentition Superior to Second

| First | Second | |
|---|---|---|
| Average | —Retarded | 4 |
| Accelerated | —Retarded | 1 |
| Accelerated | —Average | 1 |
| | | 6 = 12% |

### DENTITION AND STATURE

The relationship of dentition to stature between five and a half and eight years cannot reliably be described by the coefficient of correlation. Because there are present in all the age groups a number of children with no permanent teeth, the result is often a skew distribution with the standard deviation greater than the average. The method used in preparing the following tabulation was to compare the average number of permanent teeth in each age group of the total series (from the physician's records) with the average number present in children over or under the mean height by more than a half inch. At each age, the dentition of the tall children surpassed that of the short children.

| Age, Years | | Teeth | |
|---|---|---|---|
| | Tall Children | Entire Group | Short Children |
| | Boys | | |
| 5 Years, 6 Months | 0.3 | 0.2 | 0.1 |
| 6 Years, 0 Months | 3.2 | 2.1 | 0.9 |
| 6 Years, 6 Months | 3.6 | 3.2 | 2.4 |
| 7 Years, 0 Months | 6.7 | 6.2 | 4.8 |
| 7 Years, 6 Months | 7.4 | 7.1 | 7.0 |
| | Girls | | |
| 5 Years, 6 Months | 0.3 | 0.1 | 0.0 |
| 6 Years, 0 Months | 2.1 | 2.3 | 1.7 |
| 6 Years, 6 Months | 4.7 | 4.7 | 3.3 |
| 7 Years, 0 Months | 7.5 | 7.6 | 6.5 |
| 7 Years, 6 Months | 9.7 | 8.9 | 8.9 |

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# CHAPTER V

## THE GROWTH OF THE INDIVIDUAL

In the midst of the trends of growth described in this book, how does an individual child develop? To what extent are his size and proportions determined at an early age and how steadfastly does he maintain them? The answer lies in the Utopian future when a group of at least a hundred boys and girls of the same racial stock and economic and geographic background has submitted to full anthropometric measurements on every birthday from the first to the last.

In the meantime, assembling fragments of information, we know that tall adults were usually tall at eleven years of age and tall children of from two to seven years will most probably still be tall two, three, or four years later. Professor Boas' (10, 13) study of stature from repeated measurements of students at Newark Academy gives the first proof. The second is found in our data from the City and Country School. The rating of a child's stature in terms of his group was secured by subtracting his individual measurement from the average of his age group and dividing this plus or minus difference by the standard deviation of the group. The ratings children received the first year they were measured were then correlated with the ratings for the second, the third, and the fourth year. The results appear in the following tabulation:

| | 1st and 2nd year | | 1st and 3rd year | | 1st and 4th year | |
|---|---|---|---|---|---|---|
| Trait | Children | Correlation | Children | Correlation | Children | Correlation |
| | | Boys | | | | |
| Stature | 35 | +.77 | 32 | +.81 | 16 | +.71 |
| Shoulder Breadth | 29 | +.88 | 13 | +.76 | | |
| Radial Index | 32 | +.90 | 29 | +.90 | 20 | +.79 |
| | | Girls | | | | |
| Radial Index | 34 | +.86 | 34 | +.76 | 18 | +.83 |

At the first measurement, the age range was from two to seven years. It seems from the coefficients that a child tends to maintain his first rating during the next four years. For a different trait, shoulder breadth in which there is only a three-year range of records, the coefficients show an equal tendency toward stability of relative position. The correlations were not carried out routinely for all parts of the body measured, because of the small number of individuals.

The constancy with which the relative acceleration or retardation of an individual's ossification persists over a period of years is indicated by the coefficients for the rating of the radial index, and for repeated measurements of carpal area from the Iowa study. Age groupings of either of these traits are characterized by a high degree of individual variability. The correlations obtained by Baldwin, Busby, and Garside ((5), page 45) for total carpal area at six years and eight years are +.90 for both boys and girls and +.71 for boys at eight and ten. The coefficients for the ratings of radial indices in our own study are +.90, +.90, +.79 for boys and +.86, +.76, +.83 for girls between the first and second, first and third, and first and fourth year of measurement.

All this indicates that from an early age, a child, unless he is accelerated or retarded by change to a better or a worse environment or checked by severe illness, will continue to grow at an approximation of his original rate in relation to others of his racial and social group. If he is tall at two years of age, he is likely to be tall at twenty. And although the range of individual constitutional differences is considerable even in the most homogeneous groups, he will probably have legs and a trunk longer than the average, and broader shoulders and hips. With lesser certainty, his ossification during childhood may be accelerated and his dentition advanced. Whatever the development of a single child may be, the tendency of the human body is to grow with the various parts proportionate to one another in all stages from fetal life to maturity and for all parts to increase in harmony to total stature.

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